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Geology and structure of the Sundarijal–Melamchi area, central Nepal

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ABSTRACT

In the Sundarijal–Melamchi area, the following lithological units are identified based on detailed field mapping: the Talamarang Formation (dark grey feldspathic schist and banded gneiss with garnet and kyanite), Gyalthum Formation (thin- to thick-banded, light grey to grey, laminated quartzite with mica partings and bands of feldspathic schist, garnetiferous schist, and gneiss), Bolde Quartzite (grey to light grey, very thick-banded, massive quartzite with mica parting and schist bands containing sillimanite), Timbu Formation (light grey to dark grey, intensely deformed and folded quartzite, gneiss, and migmatite with abundant sillimanite), and Golphu Formation (grey to dark grey feldspathic schist and banded gneiss with large pegmatite veins) from bottom to top, respectively.

The Main Central Thrust (MCT) crosses the Indrawati River north of Majhitar and continues towards the Dhand Khola to SE and joins with the Mahabharat Thrust. It is moderately steep and dips essentially due NW. The footwall of the MCT is made up mainly of slate and phyllite and the grade of metamorphism is quite low in comparison with that of the hanging wall. The inverted metamorphism is conspicuous in the hanging wall of the MCT, where at first garnet schist is observed, which passes rapidly upwards to kyanite schist and then to sillimanite-bearing schist, gneiss, and migmatite.

Augen and banded gneisses invade the upper part of the northern limb and most of the southern limb of the Patibhanjyang Anticline. Apparently, the Sheopuri Injection Gneiss Zone is a continuation of the Kutumsang Gneiss Zone in the north, and the rocks were folded after the emplacement of the injection gneisses.

INTRODUCTION

Though many geologists have studied the stratigraphy and structure of the Kathmandu region (Fig. 1) since last 125 years or so, there still remain some unsolved problems. Since Heim and Gansser (1939) first proposed the term Main Central Thrust (MCT) and Gansser (1964) showed it throughout the Himalaya, there have been many controversial interpretations on the position of the fault, and the Kathmandu region is no exception. Heim and Gansser (1939) described the MCT as a tectonic surface separating the terrigenous–carbonate autochthone and the overlying metamorphic complex of micaschist and gneisses. Subsequently, Valdiya (1980) redefined the MCT as a thrust lying further north and called it the Vaikrita Thrust. Shackleton (1981) suggested it to be the limit of the Higher Himalaya and the Lesser Himalaya. He pointed out that instead of a single metamorphic break, there is a steep metamorphic gradient, implying that the MCT must at least partly be pre-metamorphic and a shear zone rather than a single thrust.

Medlicott (1875) was probably the first geologist to visit the Kathmandu valley. He described the sedimentary and low-grade metamorphic rocks exposed to the south as well as the gneisses and high-grade rocks from the north of Kathmandu. He identified the Ordovician crinoids from the Phulchauki area. Auden (1935) came to Kathmandu after the Great Bihar–Nepal earthquake of 1934. He identified the fossil-bearing Phulchauki rocks and the Sheopuri Injection Gneiss Zone containing a few bands of calcareous gneiss near Sheopuri. He also drew a cross-section across Phulchauki and Sheopuri and correlated the rocks south of Kathmandu with those of the Tibetan–Tethys Zone, whereas the rocks of the Sheopuri Injection Gneiss Zone with the Darjeeling Gneiss. In central Nepal, Hagen (1969) reported the Nawakot Nappes made up of low-grade metamorphic rocks separated by the medium- to high-grade metamorphic rocks of the Kathmandu Nappes (Fig. 2). Arita et al. (1973) identified the Sheopuri Injection Gneiss Zone, Gosainkund Gneiss Zone, and Nawakot Metasediment Zone. They also showed many vertical faults around Kathmandu. Ishida and Ohta (1973) mapped the area southeast of Kathmandu and reported staurolite, kyanite, and sillimanite from the northern limb of the Mahabharat Synclinorium (Fig. 3).

Stöcklin and Bhattarai (1977), and Stöcklin (1980) divided the rocks of central Nepal into the Nawakot Complex and Kathmandu Complex separated by the Mahabharat Thrust (MT), and they considered the MCT as a continuation of the MT in the north. However, Rai (1998), Upreti (1999), and Upreti and Le Fort (1999) separated the MT from the MCT and drew the MCT along the northern border of the Kathmandu valley. They also introduced a new thrust sheet called the Gosainkund Nappe overlying the Kathmandu Nappe, however Johnson et al. (2001) denied the existence of such a nappe. These diverse views clearly point out to the lack of a comprehensive investigation in that area.

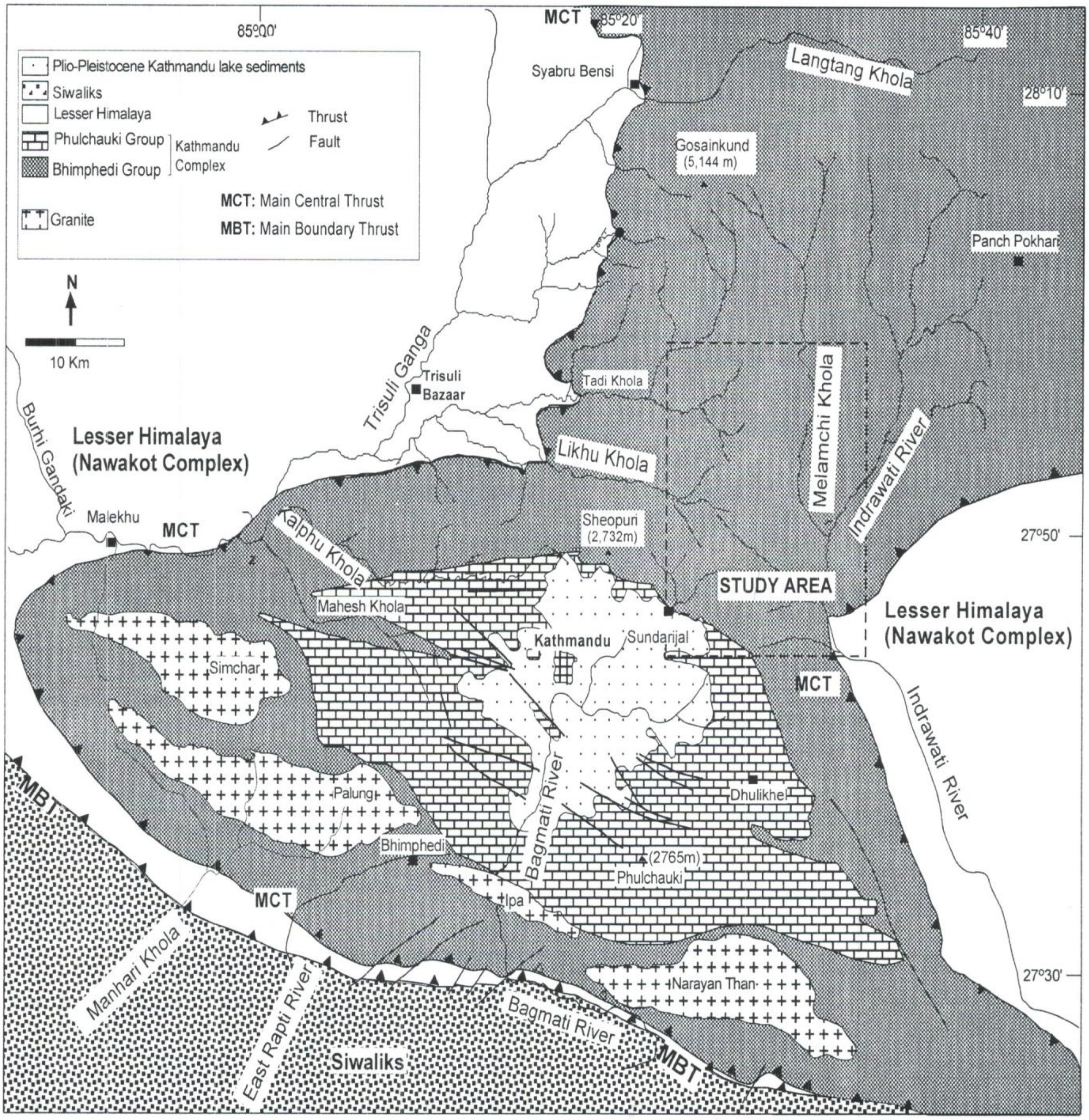


Fig. 1: Geological map of central Nepal and position of the study area (modified from Stöcklin 1980; Amatya and Jnawali 1994).

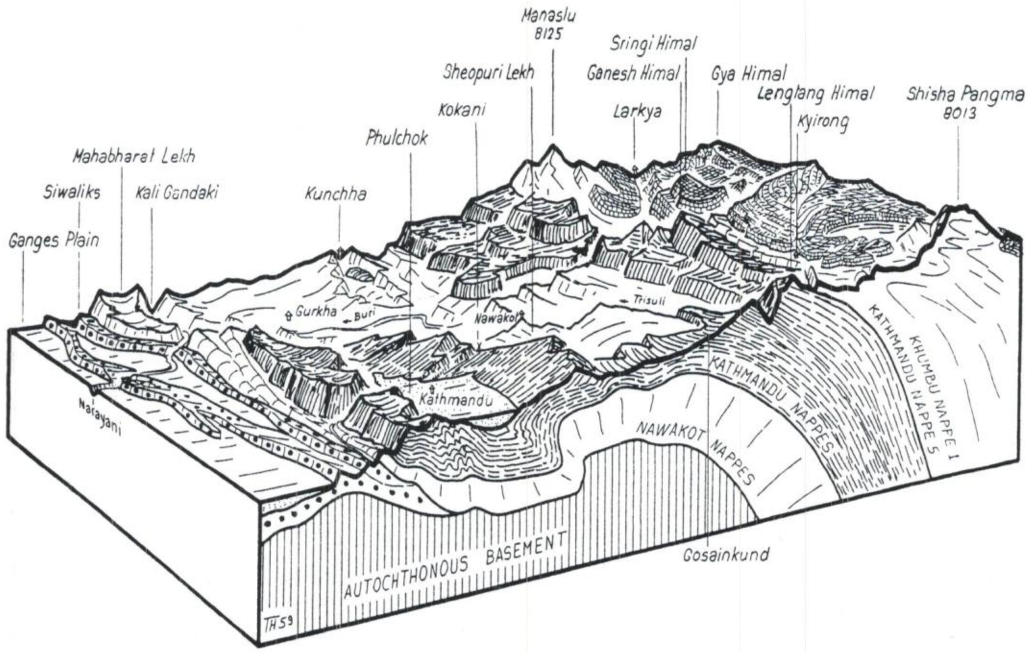


Fig. 2: Block diagram showing the Nawakot Nappes, Kathmandu Nappes, and the Gosainkund "Tectonic Bridge" in central Nepal (after Hagen 1969).

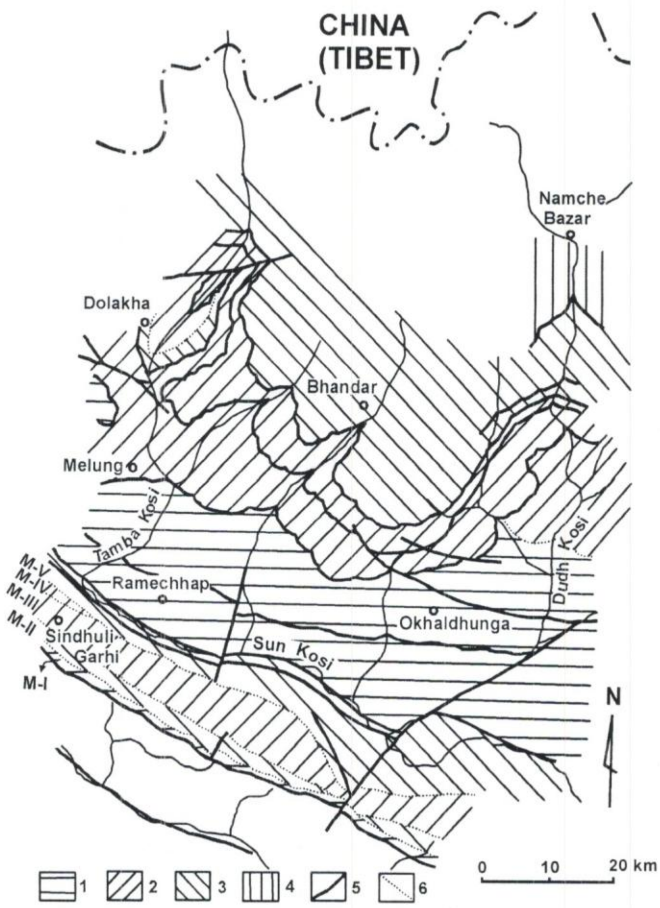


Fig. 3: Occurrence of staurolite, kyanite, and sillimanite in Zone M-V (northern limb of the Mahabharat Synclinorium) in the Ramechhap–Okhaldhunga region, southeast of Kathmandu. 1: chlorite zone; 2: biotite zone; 3: garnet-, staurolite-, kyanite zone (with some sillimanite in M-V); 4: sillimanite zone; 5: fault; 6: intrusion boundary (after Ishida and Ohta 1973).

Detailed field mapping on a scale of 1:25,000 was carried out in the area north of Kathmandu between Sundarijal and Melamchi to delineate the MCT as well as to reveal the lithostratigraphy and structure of the region.

LITHOSTRATIGRAPHY

The medium- to high-grade metamorphic rocks of Precambrian age constitute most of the study area (Fig. 1 and 4). They belong to the Kathmandu Complex and are thrust over the Benighat Slates of the Nawakot Complex along the MCT. The Benighat Slates crop out in the southeastern corner of the study area (Fig. 1 and 4) and constitute the footwall of the MCT. They comprise dark grey to black slates and green-grey phyllites with a few Jhiku carbonate bands, and are more than 2 km thick.

Owing to the higher grade of metamorphism, intense deformation, and changes in lithofacies as well as the presence of various types of gneisses, pegmatites, and migmatites, it is not possible to delineate all the formations of the Kathmandu Complex proposed by Stöcklin and Bhattarai (1977). Therefore, the following formations are separated based on field mapping (Table 1; Fig. 4 and 5).

Talamarang Formation

The name of the formation is derived from Talamarang (Fig. 4 and 5), a small village located at the confluence of the Talamarang Khola and Melamchi Khola. The Talamarang Formation is well exposed at Bahunepati, Melamchi, and Sera. It is light grey to dark grey in colour and contains bands of kyanite schist, garnetiferous schist, banded gneiss, and quartzite (schist = 40–50%, gneiss = 30–40%, and quartzite = 5–10%). On the left bank of the Talamarang Khola (near the bridge), there are also a few bands of white or pale green clean quartzite, which are sporadically calcareous. A zone of grey schist and gneiss lying below the calcareous quartzite band (on the left bank of the Melamchi Khola, opposite the confluence of the Talamarang Khola) contains abundant kyanite and sillimanite crystals. The contact with the overlying Gyalthum Formation is a gradual transition. The thickness in the type area is more than 2000 m.

Gyalthum Formation

The Gyalthum Formation is extensively distributed in the Gyalthum Khola, at Patibhanjyang, in the upper reaches of the Sindhu Khola, in the middle and upper reaches of the Talamarang Khola, at Sirse, Thankune, Urleni, Baseri, Thulobhanjayng, Thakani, and Palchen (Fig. 5). It constitutes the core of the Patibhanjyang Anticline along the Sindhu Khola, where many pegmatite veins are seen in the schist and gneiss (Fig. 6). The Gyalthum Formation is represented by thin to thick-banded, light grey to grey, laminated quartzite with mica partings (70–80%); bands of feldspar-garnet-biotite schist (20–30%); and augen gneiss (5%). The quartzite is frequently laminated and shows cross-bedding (Fig. 7). Many generations of pegmatite and feldspar veins intersect the rock (Fig. 8). There are also many conspicuous small-scale folds and faults in it. The Gyalthum Formation passes into the overlying Bolde Quartzite and is about 1700 m thick.

Sheopuri Injection Gneiss Zone

In the Sundarijal–Chisopani area, banded gneiss, augen gneiss (Fig. 10), and occasional granitic gneiss are observed within the Gyalthum Formation (Fig. 4). They constitute the Sheopuri Injection Gneiss Zone (banded gneiss = 80–85%, augen gneiss = 10–15%, and granitic gneiss = 5%). Near Patibhanjyang, the banded gneiss is interfingering with the

Table 1: Main lithological subdivisions of the Kathmandu Complex in the study area.

Formation	Lithology	Thickness (m)
Golphu Formation	Grey to dark grey feldspathic schist and banded gneiss with bands of quartzite, large pegmatite veins, and grey augen gneiss	>700
Timbu Formation	Mainly light grey to dark grey migmatite alternating with intensely deformed and folded quartzite, schist, and banded gneiss with abundant silimanite	950-1100
Bolde Quartzite	Grey to light grey, very thick-banded, massive quartzite with mica partings and schist bands with silimanite, kyanite, and garnet	400-500
Gyalthum Formation	Thin- to thick-banded, light grey to grey, laminated quartzite with mica partings, and bands of feldspathic schist, garnetiferous schist and gneiss, augen gneiss, granitic gneiss, and banded gneiss	1200-1700
Talamarang Formation	Dark grey feldspathic schist, banded gneiss, and laminated quartzite with garnet and kyanite	>2000

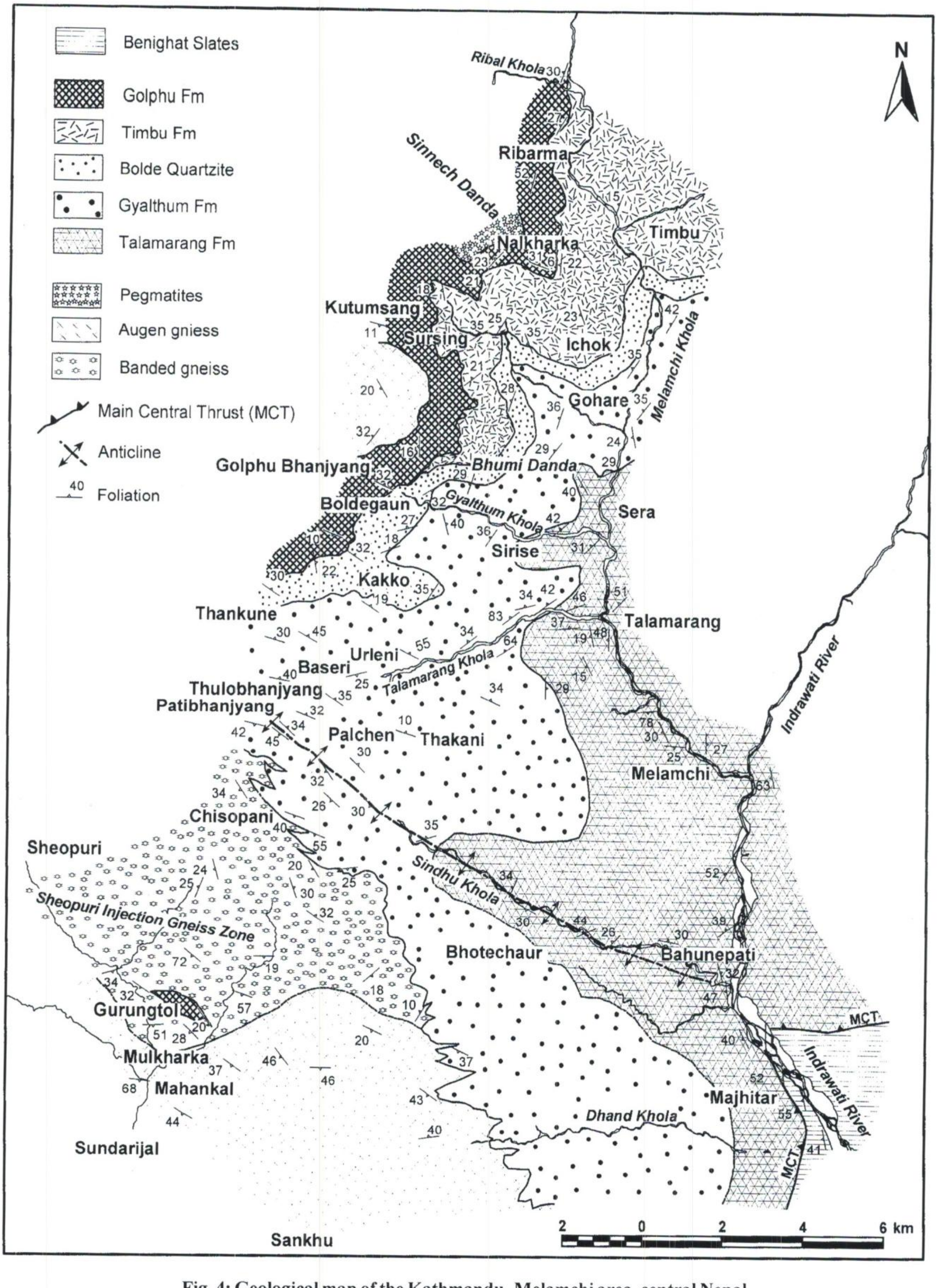
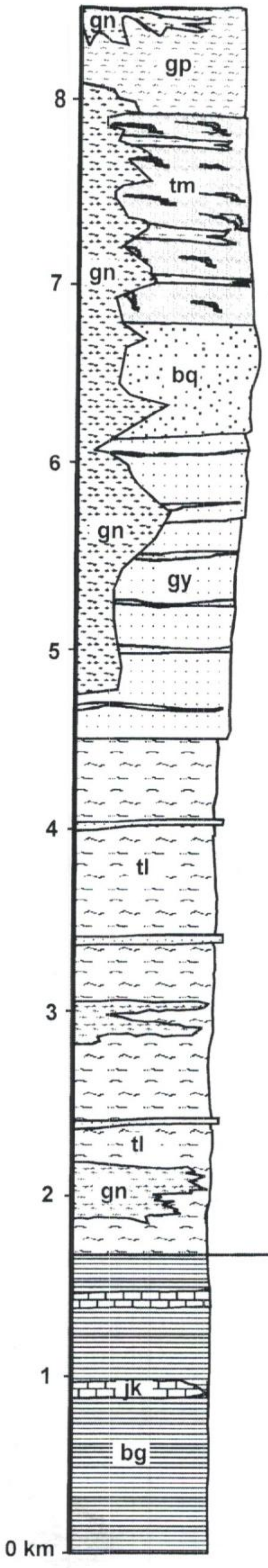


Fig. 4: Geological map of the Kathmandu–Melamchi area, central Nepal



KATHMANDU COMPLEX

Golphu Formation (gp)
Coarse-grained grey to dark grey feldspathic schist
with bands of grey quartzite and banded gneiss.
Grey augen gneiss (gn) is observed between Golphu Bhanjyang and Kutumsang.

Timbu Formation (tm)
Light grey to dark grey migmatite and banded gneiss
Minor amount of feldspathic schist and quartzite
with sillimanite

Bolde Quartzite (bq)
Very thick banded, massive, grey to light grey quartzite
with schist partings containing sillimanite, kyanite, and garnet

Gyalthum Formation (gy)

Thick to thin bands of grey to light grey laminated quartzite
alternating with garnetiferous schist

In the Sheopuri area (between Sundarijal and Chisopani),
banded gneiss, augen gneiss, and granitic gneiss
belonging to the Sheopuri Injection Gneiss Zone (gn)
are observed.

Talamarang Formation (tl)
Alternating bands of grey to light grey kyanite schist
and banded gneiss

Main Central Thrust (MCT)
NAWAKOT COMPLEX

Benighat Slates (bg)
Grey to dark grey slates
with Jhiku carbonate bands (jk)

Fig. 5: Generalised lithostratigraphic column of the Kathmandu–Melamchi area, central Nepal.

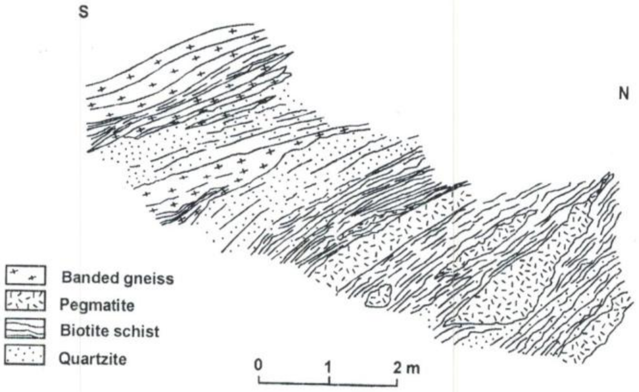


Fig. 6: Pegmatite veins and banded gneiss in the schist and quartzite of the Gyalthum Formation on the slope south of Patibhanjayng.

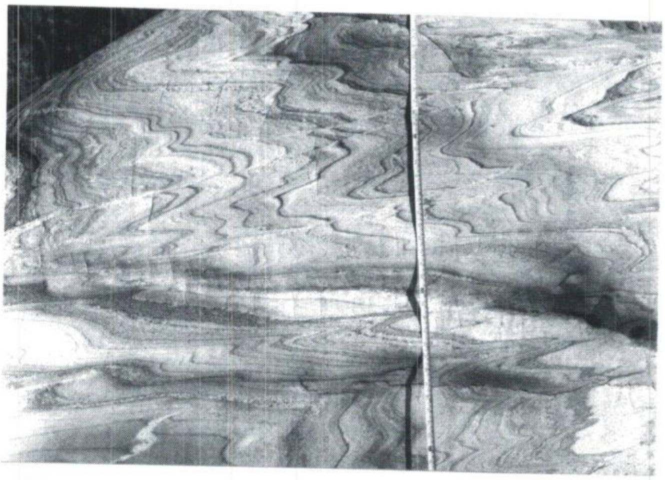


Fig. 7: Laminated quartzite of the Gyalthum Formation in the Gohare Khola.

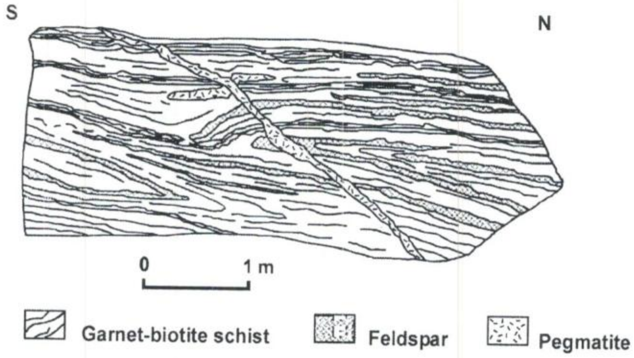


Fig. 8: Various generations of pegmatite and feldspar veins intersecting the quartzite and schist of the Gyalthum Formation on the slope north of Thulobhanjyang.

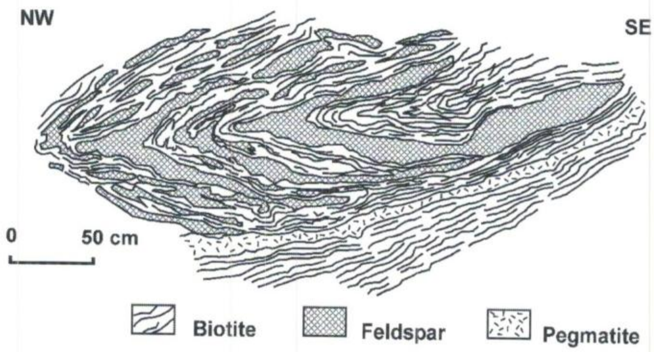


Fig. 9: Sketch showing details of the Sheopuri Injection Gneiss at Mulkharka.

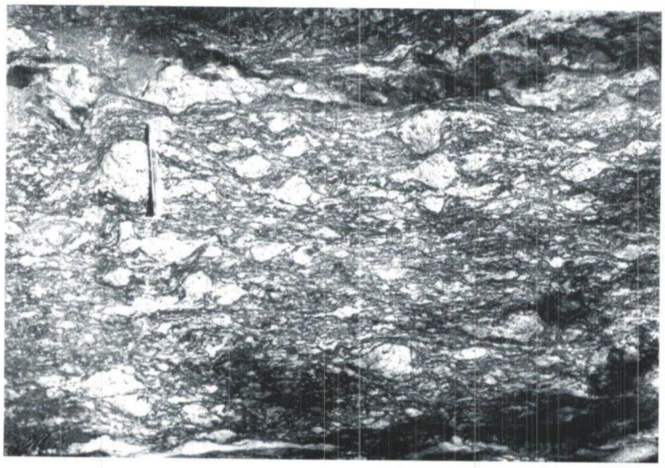


Fig. 10: Augen gneiss from the Sheopuri Injection Gneiss Zone, on the left bank of the Nagmati Khola near Sundarijal.

laminated quartzite. The augen gneiss is present at Mahankal and Mulkharka (Fig. 9), and a small band of it is also seen in the Chisopani area. The granitic gneiss is sporadically observed in the upper section. Xenoliths and bands of laminated quartzite and micaschist are common in the Sheopuri Injection Gneiss Zone. For example, about 125 m thick micaschist band (? Golphu Formation) is present at Gurungtol (Fig. 4).

Bolde Quartzite

The Bolde Quartzite is exposed at Boldegaun, Kakko, Bhumidanda, and south of Timbu (Fig. 4 and 5). It is composed essentially of thick- to very thick-banded, massive, medium- to fine-grained grey quartzite with mica partings. There are also a few sillimanite-bearing thin schist bands. The quartzite is frequently laminated. Minor cross-bedding and graded bedding can sporadically be seen in the quartzites. The upper part of the Bolde Quartzite gradually passes into the overlying Timbu Formation or the Golphu Formation (in the western part of the study area). The total thickness of the Bolde Quartzite is about 500 m.

Timbu Formation

The Timbu Formation crops out around the village of Timbu (Fig. 4 and 5). It is represented by light grey to dark grey migmatite (60–70%), intensely deformed and folded quartzite (10–15%), banded gneiss (10–15%), and schist (5–10%) with abundant sillimanite. The Timbu Formation is a discontinuous unit lying between the Bolde Quartzite at the base and the Golphu Formation at the top. The migmatite zone occupies mainly the central and upper parts of the formation and exhibits various types of ptygmatic folds, small-scale faults, and flow structures (Fig. 11). Thick quartzite is present at the lower portion, and some small bands are distributed throughout this formation. Similarly, 5 to 15 m thick garnet-biotite schist is present at the suspension bridge of Timbu and to NW of Ichok. The gneiss is observed mainly in the lower part of the Timbu Formation, but small bands are also seen within the migmatite zone. The maximum thickness of the Timbu Formation is about 1100 m.

Golphu Formation

The name of the formation is derived from the Golphu Bhanjyang, where it is well exposed (Fig. 4 and 5). It is also observed west of Sursing, at Nalkharka, Ribarma, and in the Ribal Khola. The rock is represented by coarse-grained, thick-banded, dark grey feldspar-garnet-biotite schist (60–70%), and banded gneiss (30–40%) with a few bands of laminated quartzite (5–10%). The bands are sometimes crenulated. There are many pegmatite veins in it. A large pegmatite body is present at Sinnech Danda and a zone of augen gneiss lies between Kutumsang and Golphu Bhanjyang. The Golphu Formation is more than 700 m thick.

GEOLOGICAL STRUCTURE

Except for the southeastern corner, the entire study area lies above the MCT (Fig. 4 and 12). The main geological structures observed in the hanging wall of the MCT are the Patibhanjyang Anticline, the Kakko folded zone, and other small-scale folds and faults.

Main Central Thrust (MCT)

Auden (1935) mentioned the inverted grade of metamorphism in the Kathmandu area and Hagen (1969) classified the rocks based on metamorphic grade into the Kathmandu Nappes and Nawakot Nappes. According to him, the MCT separates the Nawakot Nappes of footwall (made up of low-grade metamorphic rocks) from the Kathmandu Nappes (containing medium- to high-grade metamorphic rocks) of hanging wall. He also stated that the rocks of the Kathmandu area are connected with the Higher Himalayan rocks by the Gosainkund Tectonic Bridge (Fig. 2).

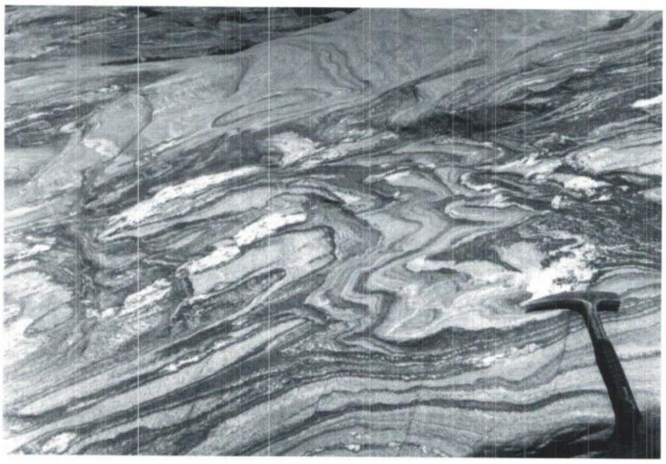


Fig. 11: Small-scale folds in the migmatite on the left bank of the Melamchi Khola, near Timbu.

In the Sundarijal–Melamchi area, the MCT crosses the Indrawati River near Majhitar and continues to SE, towards the Dhand Khola (Fig. 4). It is moderately steep (30°–40°) and dips due NW. The MCT overrides about 50 m thick garnet-chlorite schist that rests over a 25 m thick fine-grained white quartzite (? Dunga Quartzite). The dark grey to black Benighat Slates lie below the quartzite.

In the study area, the inverted metamorphism is well observed, especially in the hanging wall of the MCT. The footwall of the MCT is made up of slate and phyllite and the grade of metamorphism is quite low in comparison with that of the hanging wall. Already in the footwall, a few small garnets appear towards the top. This grey-green chlorite-garnet zone rapidly passes upwards into the dark grey garnet schist and then kyanite schist of the hanging wall belonging to the Talamarang Formation. Kyanite is observed throughout the Talamarang Formation (e.g. in the Sindhu Khola, at Bahunepati, Melamchi, and around Talamarang). Sillimanite appears first in the upper part of the Talamarang Formation about 750 m below the Bolde Quartzite and becomes abundant in the Timbu Formation. Sillimanite was also observed NE of Sankhu.

The schematic cross-section (Fig. 12) depicts the kyanite (ky) zone along the MCT and the sillimanite (sil) zone *(crosshatched)* as pockets just above it. The sillimanite zone is followed again by the kyanite (ky) and garnet (ga) zones *(black dots)*. There is a large gneiss (gn) injection *(ornamented),* which assimilates the country rock. There are also many pegmatite veins (pg) around the injection gneiss.

There is no inverted metamorphism in the Sankhu–Mahesh Khola area, as the grade of metamorphism decreases towards the south – in the direction of younging of rocks as well as the dip direction of foliation. Since the MCT zone is invariably characterised by the inverted metamorphism, these rocks do not constitute such a zone.

Stöcklin and Bhattarai (1977), and Stöcklin (1980) mapped the Mahabharat Thrust up to the Dhand Khola and inferred its continuation in the vicinity of Majhitar. They also stated that the MT and the MCT are the same fault. Present study demonstrated that the MT directly continues to the north and becomes the MCT, and there is only one continuous thrust fault in south-central Nepal. Hence, the study refutes the existence of any other regional thrust fault north of the Mahabharat Thrust.

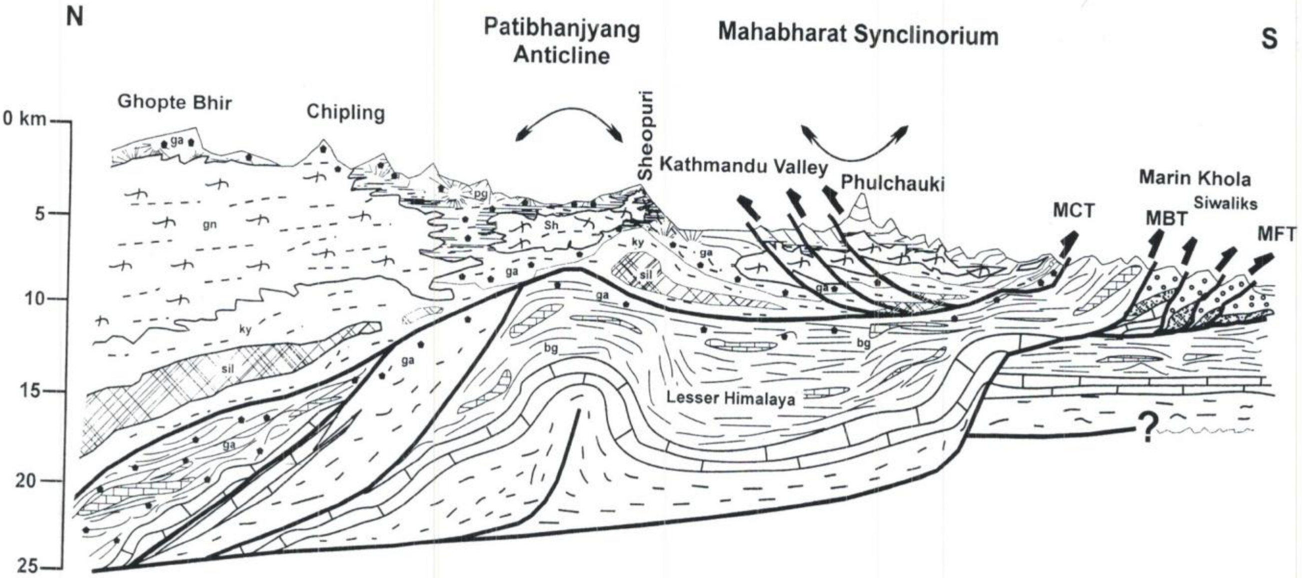


Fig. 12: Schematic geological cross-section across central Nepal.

Patibhanjyang Anticline

The Patibhanjyang Anticline is one of the main structural features of the study area (Fig. 12). Its axial trace passes through the Sindhu Khola (Fig. 4). The northern limb of it is moderately dipping due NW whereas the southern limb is moderately to steeply dipping due SW. The fold is gently (10–20°) plunging due NNW. The upper part of the northern limb and most of the southern limb of the Patibhanjyang Anticline are invaded by gneisses. One of the remarkable aspects in the distribution of gneisses is that the banded gneiss is found either near the MCT or in the core of the anticline, and the gneiss lying away from the MCT or the core is mainly of augen-type. It is most probably related to the deformation during thrusting and formation of the anticline. It seems that the Sheopuri Injection Gneiss Zone is a continuation of the Kutumsang Gneiss Zone to the north, and the rocks were folded after the emplacement of granite and injection gneiss.

Other structures

Small-scale to mesoscopic S- and Z-type folds prevail in the study area. A small (about 2 km wide) open fold is observed at Kakko. Its synclinal core is made up of the Bolde Quartzite (Fig. 4). The fold has gently foliated (10-30°) limbs and horizontal core zone. In the Talamarang Khola, there are many mesoscopic folds (amplitudes varying from 5 to 50 m) plunging essentially due NW.

CONCLUSIONS

The rocks of the study area are divided into the kyanite- and garnet-bearing schist, quartzite, and gneiss of the Talamarang Formation; the laminated quartzite with thin schist bands belonging to the Gyalthum Formation; the massive Bolde Quartzite; the migmatite, quartzite, and gneiss of the Timbu Formation; and the feldspathic schist and banded gneiss of the Golphu Formation, respectively in an ascending order. Apart from these rocks, there are large areas occupied by augen gneiss and banded gneiss between Sundarijal and Chisopani as well as between Kutumsang and Golphu Bhanjyang.

The MCT passes through the Indrawati River near Majhitar and continues to SE. It is moderately steep (30–40°) and dips due NW. The inverted metamorphism is conspicuous, especially in the hanging wall of the MCT, where the garnet schist is followed upwards by the kyanite schist and sillimanite gneiss. There is only one continuous thrust fault equivalent to the MCT or MT in south-central Nepal and there is no other regional thrust fault above the MT.

A major structure of the study area is the Patibhanjyang Anticline whose northern limb is moderately dipping due NW and the southern limb is moderately to steeply dipping due SW. The Sheopuri Injection Gneiss Zone and Kutumsang Gneiss Zone occupy respectively the southern and northern limbs of the anticline, whereas the banded gneiss is found either near the MCT or in the core of the Patibhanjyang Anticline. This type of preferred distribution pattern resulted most probably from deformation during thrusting and formation of the anticline after the emplacement of injection gneisses. In the past, the Sheopuri Injection Gneiss Zone continued up to the Kutumsang Gneiss Zone in the north and the two zones were separated after erosion of the anticlinal core.

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