Bulletin of the Geological Survey of Japan, vol. 39 (4), p.205-249, 1988 551.241/.72/.781(541.35)

Geology of the southern part of the Lesser Himalaya, West Nepal

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HIRAYAMA, J., NAKAJIMA, T., SHRESTHA, S. B., ADHIKARI, T. P., TULADHAR, R. M., TAMRAKAR, J. M. and CHITRAKAR, G. R. (1988) Geology of the southern part of the Lesser Himaraya, West Nepal. *Bull. Geol. Surv. Japan*, vol. 39(4), p.205-249.

Abstract: The survey areas consist of three belts, two of which are subperpendicular to the structural trend and the rest is subparallel to the general trend. They are underlain by a thick sequence of sedimentary rocks, which is divided into two groups: Nawakot and Tansen Groups. The Nawakot Group, which is probably of Late Precambrian age, consists largely of pelitic, psammitic and carbonatic metasediments. The group is subdivided into eight formations, most of which are easily identified by their characteristic lithological and mineralogical features. The Tansen Group is restricted in a narrow EW-trending belt along the Main Boundary Thrust. It is composed mainly of pelitic and psammitic sediments with Paleogene fossils and ferruginous sediments and is subdivided into two formations.

Geologic structures in the present areas are characterized by imbrication structures resulted from numerous thrusts and EW-trending folds and block faults. Most of the anticlinal structures have been destroyed by the longitudinal block faults. To the south of Tansen, a large nappe composed of the Nawakot Group concordantly overlies the Tansen Group and forms a synclinal structure with the underlying Tansen Group. It indicates that the thrusting started after the deposition of the Tansen Group, probably in the Oligocene, followed by EW-trending folding and then longitudinal block faulting.

Introduction

While the Himalayan Range extends for approximately 2,500 km from east to west, the Nepal Himalaya occupies its central part, extending about 800 km along the latitude and 150 to 250 km along the meridian. The High Himalaya, underlain by highly crystalline metamorphic rocks and the overlying Tethys sediments, forms the northern border of Nepal. The High Himalaya is flanked by a wide belt of rugged mountains on the southern side, which mostly range from 2,000 to 3,000 m or more in altitude and is called the Midland or the Lesser Himalaya. The Lesser Himalaya is separated from the High Himalaya by the Main Central Thrust (MCT) and composed of a thick sequence of unfossiliferous metasediments, which is locally succeeded by Mesozoic to Tertiay sediments. These rocks involved in complicated tectonic disturbances are overlain by many thrust sheets of highly-metamorphosed rocks derived from the High Himalayan areas.

The Lesser Himalaya is separated from the southern foothills composed of the Siwalik Formations of molasse type by the Main Boundary Thrust (MBT).

The present areas devoid of crystalline nappes between the MCT and MBT are characterized by the most extensive distribution of the metasediments in the Lesser Himalaya.

Soon after Nepal opened the borders to

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foreigners in 1950, Hagen started his 12-year-long geologic work in the whole of Nepal and published a structural review (HAGEN, 1969). Subsequently, the present areas were investigated by GANSSER (1964), TATER (1967), FRANK and FUCKS (1970), FUCKS and FRANK (1970), TALALOV (1972), and HASHIMOTO *et al.* (1973). These investigations were mostly carried out along routes of easier access to cover as large areas as possible in short times. Such reconnaissance surveys resulted in widely different interpretations on the geology among the workers in the present areas. Particularly, HAGEN (1969) and TALALOV (1972) provided extremely contrasting interpretations. While the former interpreted the geology by complicated nappe-systems, the latter explained it exclusively in terms of folds and block faults. Although the other workers accepted more or less nappe-structures, the views on the details of the stratigraphy and geologic structures differ considerably from each other.

A regional geological mapping project, which was based upon toposheets in a scale of 1 inch to 1 mile (1 : 63,360), was undertaken by the Department of Mines and Geology (DMG), His Majesty's Government (HMG) of Nepal mainly in the 1970s. Although most parts of the Lesser Himalaya were covered by the large-scaled geological maps, the adjacent maps were so poorly consistent with each other due to the very complicated structures that the compilation of geologic maps in a scale of 1 : 250,000 on the basis of the larger-scaled maps was contemplated. In order to facilitate the compilation work, a new programme called the River Section Project was initiated by DMG in 1980. The main purpose of the project is to elucidate the stratigraphy and geologic structures of strata distributed along the major rivers and their distributaries in the Lesser Himalaya. Two Japanese geologists joined the field works, which were conducted in the catchment areas of the Kali Gandaki and Seti Rivers in Western Nepal in 1980/81 period, to demonstrate how to make route maps, find and trace marker beds or units, and compile geologic maps on the basis of the collected data to the counterparts.

The present areas are divided into three parts, which are designated the Tansen-Syangja, Kheireni-Basini and Syangja-Kheireni areas, respectively. The first extends northeast and subperpendicular to the structural trend for about 50 km along the Pokhara-Tansen-Bhairawa Highway, ranging in width from 2 to 17 km. The second stretches southward from Kheireni, which is located about 20 km east of Syangja, extending perpendicular to the general trend for about 35 km with a width of 4 to 11 km. Both of the areas are about 40 km far away from each other along the MBT. The third area extends for about 20 km along the general trend between the first and second areas, ranging 9 km in east to 19 km in west in width (Fig. 1). The three areas will be called the area I, II and III, respectively, for convenience in further description.

In 1980/81 period, two 45-day-long field trips were carried out by J. HIRAYAMA, T. NAKAJIMA, S. B. SHRESTHA, and T. P. ADHIKARI. The first trip and two additional check-surveys were devoted to the area I, whilst the second one to the area II. The area III was surveyed by J. HIRAYAMA, R. M. TULADHAR, J. M. TAMRAKAR and G. R. CHITRAKAR, spent a total of 265 man-days in 1981/82 period.

All traverse routse were covered by route maps in a scale of 1:4,000 to 1;5,000 by a pace and compass method. All the observations on lithology, sedimentary structures, attitude of strata, contacts, and other significant features were continuously recorded on the route maps. Each day 2- to 3-km-long routes were usually traversed by each geologist, but the covering distances were expanded up to 5 to 6 km per day along routes with less disturbed geology or monotonous lithofacies.

As described later, there are so many faults causing the repetition and missing of

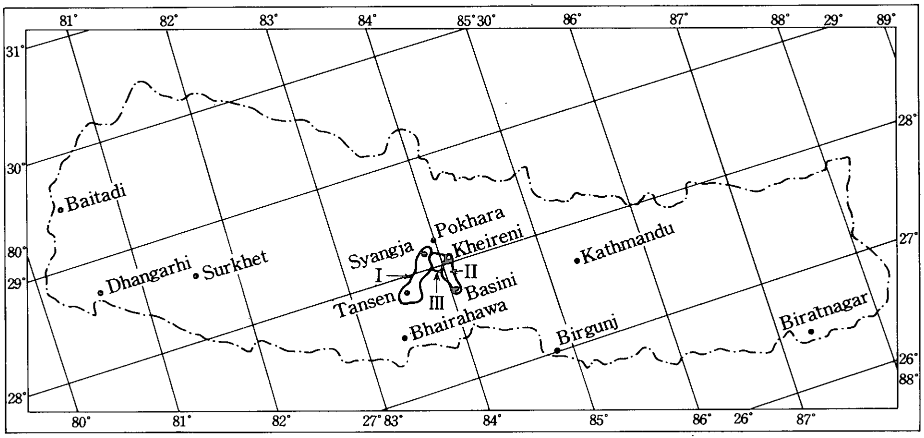

Fig. 1 Index map of the survey areas.

thick units in the mapped areas that a single or a few traverses across the general trend frequently mislead our interpretation on the stratigraphic successions. Therefore, it is desirable to trace a stratigraphic sequence observed along a survey route for a distance of at least 10 to 20 km along the strike to establish the exact stratigraphy. However, the requirement was not always fulfilled in the areas I and II because of time constraint. The total area mapped in a scale of 1:50,000 is approximately 1,100 km^2.

Acknowledgement

We would like to express our appreciation to Mr. M. N. RANA, Director General of the Department of Mines and Geology, HMG of Nepal, and J. M. TATER, Deputy Director of DMG, for the full understanding and managerial support. Mr. H. SAKAI, a Japanese postgraduate student of Kyushu University, participated in the first field trip in the Tansen-Syangja area. We are very grateful for his laborious field work and valuable discussion. Messrs. J. N. SHRESTHA, K. M. AMATYA, P. P. ADHIKARI, and R. R. SHAKYA, geologists of DMG, took part in a three-week-long field trip which was planned for training and check-survey by the first author. They greatly contributed to acquisition of valuable information for geologic interpretation and discovery of new localities of fossils in the Tansen area. Besides, Mr. J. N. SHRESTHA assisted the first author in a week-long check-survey in the Angha Khola area and the micropaleontological and petrographic studies.

The Thin Section Laboratory of DMG assisted us in making many thin sections and polished slabs. The Chemical Section carried out chemical analysis of carbonate rocks. The Mineralogical Section assisted in the separation of microfossils by a heavy liquid. Their assistance is highly appreciated.

Stratigraphy

The survey areas are underlain exclusively by a thick sequence of sedimentary rocks, which is divided into two groups: Nawakot and Tansen Groups. The Nawakot Group occupies the main part of the mapped areas and consists of pelitic, psammitic and carbonatic metasediments.

The group is subdivided into eight units in the area I and seven units in the area II as shown in Table 4. The Kuncha Formation, the lowermost part of the group, is represented by gritty phyllites, which are overlain by the Naudanda Slate characterized by orthoquartzite. The Naudanda Slate is followed by the Uniyachaur Slate composed largely of dark grey to green slate and phyllitic slate. The overlying Syangja Formation is characterized by pink dolomites and arkosic quartzites, followed by the Darsing Dolomite composed of grey dolomites. The Darsing Dolomite is covered by the Galyang Slate, which is represented by carbonaceous slate intercalated with black-colored calcareous dolomites in the lower part and the overlying banded slate. The Galyang Slate is overlain by the Angha Khola Formation in the Area I and by the Bungdi Khola Formation in the area II. They consist largely of varicolored slates, quartzites and dolomites. The Ramdighat Formation, the uppermost unit of the Nawakot group, is distributed in the area I and consists of interbedded quartzite and grey slate. Since the group is entirely devoid of any fossils except for stromatolites, it has been correlated with Upper Precambrian to Paleozoic or occasionally as young as Mesozoic rocks in the Indian Himalayas mainly on the basis of the lithologic similarity (GANSSER, 1964; HAGEN, 1969; FRANK and FUCKS, 1970; FUCKS and FRANK, 1970; HASHIMOTO *et al.*, 1973; STOCKLIN and BHATTARAI, 1977, 1980; STOCKLIN, 1980). The Nawakot Group in the survey areas presumably comprises the main part of the Nawakot Complex defined by STOCKLIN and BHATTARAI (1977, 1980) except for the uppermost and basal parts of the complex.

The Tansen Group is restrictedly distributed in the southern part of the area I and II, and consists largely of pelitic and psammitic rocks, some of which yield Paleogene fossils. The group is divided into two formations, which are given different names in each area because of different lithofacies. They are designated the Bhainskati and Dumre Formations in the area I and the Damargaon and Basini Formations in the area II, respectively, in ascending order (Figs. 5 and 6).

A. Nawakot Group

A.1 Kuncha Formation (kn)

The formation name is derived from Kuncha village in the Gorkha District (outside of the survey area), and was defined by BORDET (1961) as "Série de Kuncha" for a thick and monotonous sequence of slightly metamorphosed flysch-like sediments in the Kali Gandaki region. STOCKLIN and BHATTARAI (1977) and STOCKLIN (1980) applied the same formation name to "a rather monotonous, flysch-like alternation of phyllites, phyllitic quartzites and phyllitic gritstones (gritty phyllites) resembling greywackes" in Central Nepal including the Kathmaudu Valley. From a reference to these descriptions and an excursion to the Trisuli area where the Kuncha Formation is widely distributed, the unit described here is deemed to have a lithologic and stratigraphic similarity enough to be correlated with the formation. Consequently, the formation name is tentatively applied to the present unit for convenience.

The Kuncha Formation is found only in the northernmost part of the each area (Figs. 2,3 and 4).

In the area III, the formation forms a broad belt extending almost in a E-W direction along the Saraudi Khola. It has been traced only for a distance of about 9 km along the strike due to time constraint. Excellent exposures of the formation are found along the Saraudi Khola and its distributaries, such as Tuni and Pluri Kholas.

The present formation consists largely of a thick sequence of monotonously alternating gritty phyllites and phyllites, very subordinately intercalated with phyllitic quartzites and quartzose conglomerates. In general, the gritty phyllites predominate over the phyllites and occasionally vice versa.

The **gritty phyllites** are usually light greyish green in color, varying through grey to white-grey in weathered conditions. They are ordinarily medium- to thick-bedded, frequently attaining as thick as 150 cm or more, but are occasionally thin-bedded also. The most conspicuous feature of the gritty phyllites is detrital particles studded densely or sparsely in phyllitic matrices. The clastic particles consist dominantly of quartz, feldspar and muscovite, and less frequently tour-

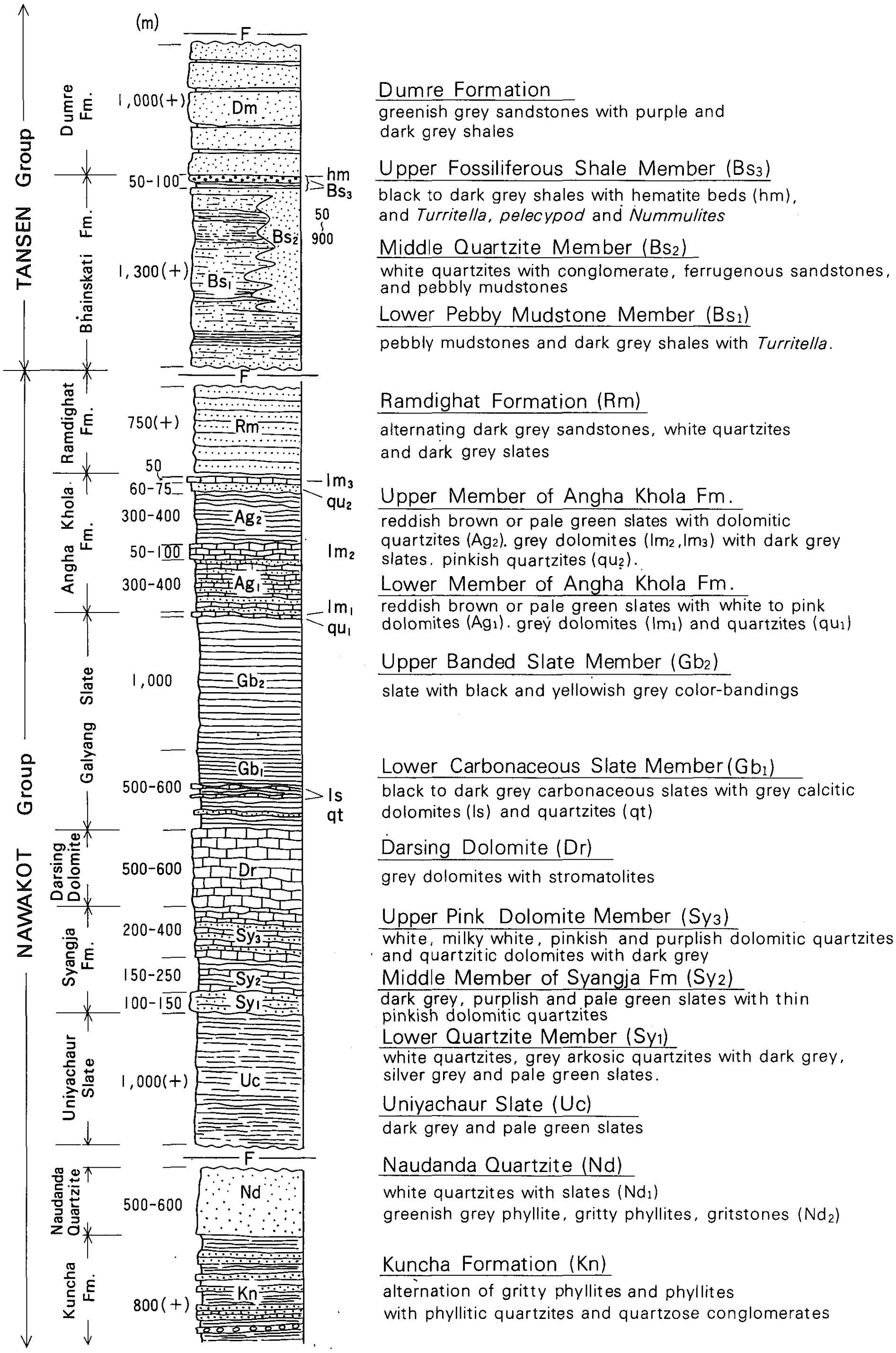

Fig. 5 Stratigraphy of the Tansen-Syangja area (area Ⅰ).

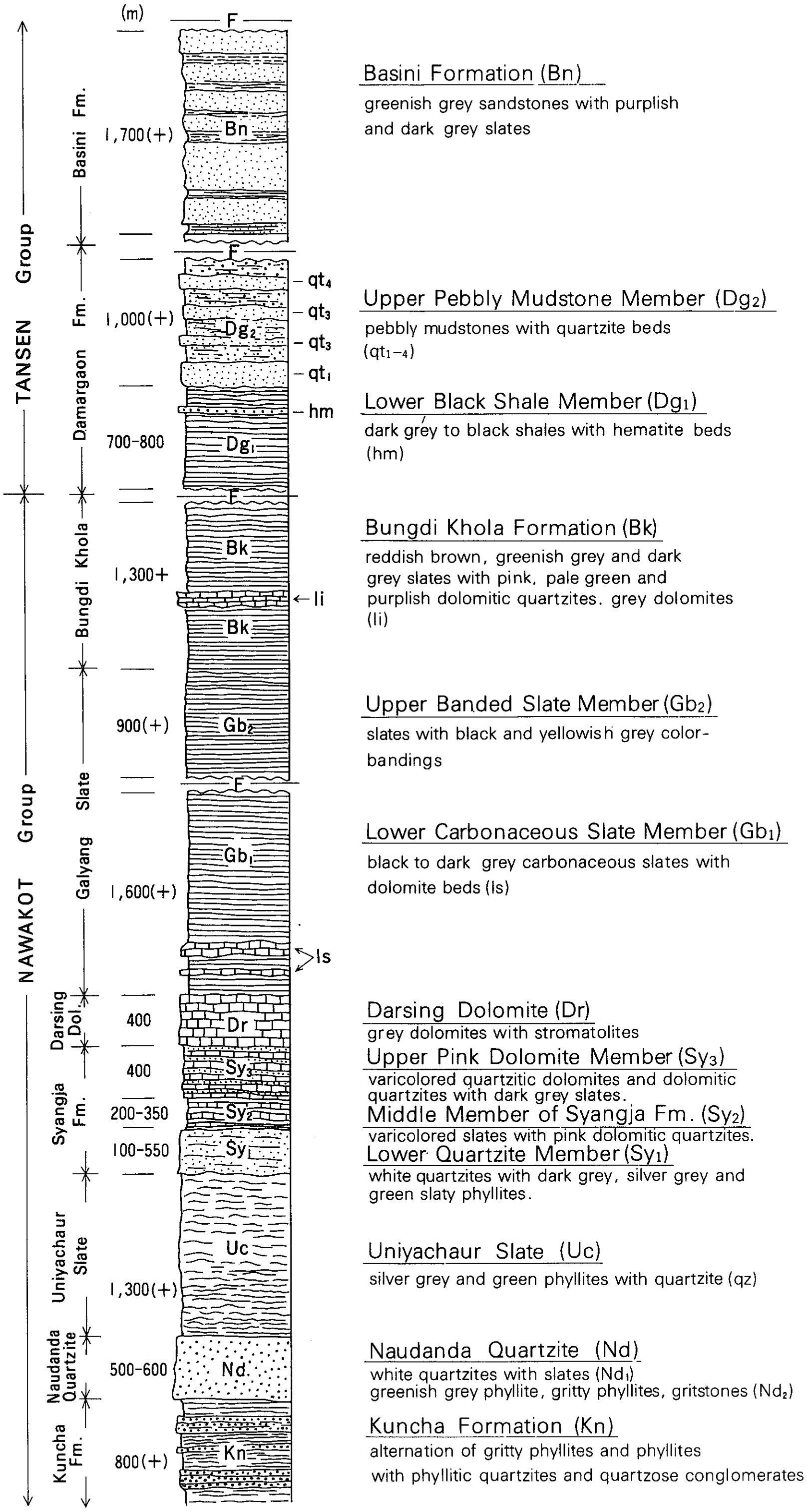

Fig. 6 Stratigraphy of the Kheireni-Basini area (area II).

maline and other minerals. Granular particles, such as quartz and feldspar, are surrounded by eye-shaped pressure shadows of silky, fine-grained matrices. The detrital grains commonly range from fine- to medium-sand grade, occasionally attaining as large as coarse sand size. These gritty phyllites are inferred to have originated from poorly-sorted sandy mudstones. Though the gritty phyllites look like compact and hard quartzites at first glance, they are much more friable than ordinary quartzites. Their surfaces are usually more or less rounded, whereas the interbedded phyllites are sharp-edged.

The **phyllites** interbedded with the gritty phyllites are commonly dark-grey to grey in color, less frequently showing a light green to olive-green color. They are extremely fine-grained, varying from clay size to subordinately silt size. They frequently exhibit papery laminations, and the splitting surfaces show a silky lustre.

Besides the major constituents mentioned above, the Kuncha Formation contains subordinate intercalations of phyllitic quartzites and quartzose conglomerates.

The **phyllitic quartzites** are locally found along the Saraudi Khola. They vary from green-grey to greyish white in color, and are more or less argillaceous. They widely range from thin- to thick-bedded, often displaying green-colored parallel laminations. More argillaceous varieties are quite dark-colored. Clean orthoquartzite resembling that of the Naudanda Formation is exceptionally exposed along the Saraudi Khola near the confluence with the Tuni Khola. It is usually medium- to thick-bedded, varying between fine and coarse sand grades. It is occasionally cross-bedded.

Another accessory constituent of the Kuncha Formation is **quartzose conglomerate**, which is restrictedly found near Sigrebas village on the Saraudi Khola. Round pebbles, which sometimes exceed 6 cm in diameter, are cemented by quartzitic matrices. Individual beds of the conglomerate barely exceed 30 cm. Though the Kuncha Formation has been affected by intense microfolding, the strata generally trend west-northwest and dip 45 to 70 S. The phyllitic rocks of the present formation have been extensively subject to a low-grade metamorphism up to chlorite facies.

The present formation is conformably overlain by the Naudanda Quartzite in the area Ⅲ. The very contact between them can be observed along the Tuni Khola and in a small stream southeast of Ahale village. Since the complete succession of the formation is not exposed in the mapped areas, the total thickness is unknown. The thickness of the formation exposed in the areas exceeds at least 800 m.

In the top part of a E-W trending ridge in the northwestern corner of the area I, phyllitic rocks resembling those in the Kuncha Formation are distributed. They consist largely of greenish grey gritty phyllites and phyllitic quartzites, concordantly overlying a correlative of the Naudanda Quartzite probably with a thrust contact.

A. 2 Naudanda Quartzite (Nd)

This unit was named after the village of Naudanda about 4 km northwest of Syangja (HIRAYAMA *et al.*, 1981, 1982). It is typically exposed along the bus road near Naudanda. The formation is distributed in three separate areas: 1) in the northern part of the mapped areas, 2) in the axial part of the Kheireni syncline in the area Ⅲ, and 3) around a mountain ridge in the northwestern corner of the area I. In the first area, the formation is continuously traced from Naudanda village in the northern part of the area I, throughout the northern part of the area Ⅲ, to the northernmost part of the area Ⅱ for a distance of approximately 30 km. In the second and third areas, it forms a narrow, horseshoe-shaped belt. Besides near the type locality, excellent exposures of the formation are found in the upper reaches of the Bhat Khola and its distributaries, and along the Tuni Khola in the area Ⅲ. This formation is considered to be correlative to the Fagfog Quartzite defined by STOCKLIN and BHATTARAI (1977) from the lithological and stratigraphic similarity.

The Naudanda Quartzite consists largely of orthoquartzite, associated with extremely subordinate intercalations of slaty phyllites.

The **orthoquartzite** is usually medium- to thick-bedded, often attaining up to 200 cm thick or more. The color is usually white and less commonly light green-grey in fresh parts. The weathered parts show pink to pinkish brown. This quartzite is very hard and compact, forming sharp-edged exposures.

The orthoquartzite is composed mainly of well-sorted quartz grains, associated with a minor amount of muscovite. The detrital quartz grains ordinarily contact each other due to the scarcity of cementing matters. Most of the X-ray charts are represented mainly by the peaks of quartz, showing some minor peaks for muscovite in the low angle area (Fig. 14). The silica contents usually exceed 90%, attaining up to more than 97% or more (Table 1).

A lot of small-scale ripple marks are observed on the bedding planes of the quartzite near the type locality. The ripples show more or less straight to slightly undulatory and parallel crests (Fig. 7). They show well-developed slipfaces, which dominantly face southwest but occasionally southeast or northeast. They range from 0.1 to 2.1 cm in height. The ripple index (L/H) varies from 4.3 to 40, mostly between 8 and 12. Asymmetrical index ranges from 1.5 to 3.

Although these indices imply the coexistence of asymmetrical wave ripples and small-current ripples (REINECK and SINGH, 1980; 35-38 p.), the following features suggest the predominance of the former over the latter: 1) unlike small-current ripples, the straight crests are regularly arranged and show frequent bifurcation in the shape of tuning fork; 2) symmetrical ripples are also found sometimes; 3) on a bedding plane, slipfaces of successive ripples of a ripple train occasionally change in direction.

In general, the orthquartzite in the present formation rarely shows laminations. Most of the laminae, which are occasionally observed, are parallel. No cross-lamination has been found even in the well-rippled quartzites. In the mapped areas except for the type locality, much less ripple marks have been encountered in the bed rocks, though many screes contain well-developed ripples.

The **slaty phyllites**, which are occasionaly intercalated in the present formation, are dark green-grey to dark grey in color, showing a silky lustre. They vary in thickness from a few cm to 5 cm or more. Near the type locality in the area I, the present formation is bounded with the overlying Uniyachour Slate by a highly-inclined fault. In the northern part of the area III, however, it is conformably overlain by the Uniyachour Slate, and the very contact can be observed in the upper reaches of the Bhat Khola. The total thickness of the formation is estimated at 500 to 600 m.

The Naudanda Quartzite in the eastern part of the Kheireni syncline thrusts over the Uniyachour Slate, forming the base of the uppermost nappe sheet.

In the northwestern corner of the area I, the Naudanda Quartzite has thrust over dark grey slates and greenish grey phyllites of the Lower Galyang Slate (Gb.) It is separated into two horizons of white quartzite by a band of greenish grey sandy slate of about 50 m thick. Unlike the quartzite near Naudanda village, the quartzite in this area is dominantly thin- to medium-bedded, occasionally intercalated with thin slate beds. The development of ripple marks is less conspicuous than near Naudanda. The 50-m-thick band of sandy slate in the white quartzite might be a thrust sheet of the Kuncha Formation, though the contacts with the adjacent quartzites have not been confirmed.

A. 3 Uniyachour Slate (Uc)

The unit is named after Uniyachour village southwest of Syangja (HIRAYAMA *et al.*, 1981),

Table 1 Chemical compositions of quartzitic rocks

Sample No.	Location	Formation	Loss of ignition	SiO_2 %	Fe_2O_3 %	Al_2O_3 %	CaO %	MgO %	Rock names
JT 81-121315	Guni kh.	Naudanda Quartzite	0.42	91.66	0.64	2.20	4.40	1.20	white orthoquartzite
JT 81-121506	north of Bhat Kh.		0.53	97.11	0.91	0.91	trace	2.02	white orthoquartzite
GR 81-121313	NW of Putalikhet		1.14	94.22	0.21	0.79	2.20	2.00	white orthoquartzite
GR 81-121304	Jhagdo Kh.	Uniyachaur State	5.25	74.60	6.07	6.49	3.30	5.25	dark green grey dolomitic quartzite
H 81-122504	east of Bhakalkot	Lower Quartzite Member(Sy_1) of Syangja Formation	2.30	90.08	0.64	4.04	2.20	3.60	arkosic quartzite
H 81-122505	〃 〃		1.00	89.42	0.85	4.23	4.40	1.20	arkosic quartzite with pink particles
H 81-122507	〃 〃		4.11	85.70	0.78	3.21	1.68	4.83	arkosic quartzite
JT 81-121503	north of Bhat Kh.		0.70	83.58	1.49	7.55	3.30	2.20	〃 〃
JT 81-122512	SW of Tuni Kh.		0.76	85.25	1.47	9.17	0.56	0.60	〃 〃

Fig. 7 Wave-generated asymmetrical ripple-marks with bifurcated crests in the Naudanda Quartzite. Taken near Naudanda.

and is typically exposed along the bus road between Belbas and Uniyachour villages. It is largely distributed in the axial part of the Syangja dome and around Chiuri village in the area I. Further, the formation repeatedly appears throughout the N-S traverse in the area III because of folding, thrusting, and block faulting. In the area II, the formation is developed on the both wings of the Kheireni syncline and on the northwestern wing of the Pirung synclinorium.

The complete succession of the present formation can be seen on the northern wing of the Kheireni syncline alone in the area III, where it is in conformable contact with the underlying and the overlying formations. The "paraautochthonous" sequence is well exposed in the upper reaches of the Tuni Khola.

The complete sequence is subdivided into three subunits. **The lower subunit** consists largely of interbedded slate to phyllitic slate and quartzitic sandstone. The alternating rocks are usually thin- to medium-bedded. The slate ordinarily predominates over the sandstone with occasional exceptions.

The **slate** is usually dark grey to black in color, but green-colored varieties are also found commonly. The slate is mostly more or less phyllitic and exhibits a silky lustre. The dark color of the fresh parts changes into light grey or light yellowish grey when weathered. Most of the slates show shaly laminations, which show up as fine bands of dark and light colors in weathered parts. The slate usually split into thin slabs along cleavages that are extensively developed nearly parallel to the laminations. The dark grey slate frequently exhibits a characteristic color-banding reminiscent of "Tiger Bands" slate, which is a main constituent of the Upper Galyang Slate (Gb_2) and is widely distributed in the areas I and II. As compared to the "Tiger Bands" slate, the banding in the present unit is rather thinner and characterized by a rhythmic alternation of black to dark grey bands and light grey to white bands (Figs. 8 and 9). Each band is usually a few mm thick, rarely exceeding 1 cm thick. We nicknamed the banded slate "Micro-tiger Bands".

The **quartzitic sandstone** alternating with the above-mentioned slate is usually dark grey to dark green-grey in color, less frequently white. It is ordinarily very fine- to fine-grained and poorly laminated. Medium-bedded strata exceeding 10 cm thick occasionally exhibit planar-type cross-bedding. The sandstone consists largely of quartz, containing a small amount of dolomite, muscovite, feldspar and chlorite. The silica content is lower than that of orthoquartzites in the Naudanda Quartzite and arkosic quartzites in the Lower Syangja Formation, not exceeding 80% (Table 1). The thickness of the lower subunit is estimated at about 120m.

The **middle subunit (qz)** of the Uniyachour Slate consists largely of white orthoquartzite resembling that in the Naudanda Quartzite, intercalated with dark grey to black phyllitic slate. The orthoquartzite is ordinarily thick-bedded, varying from

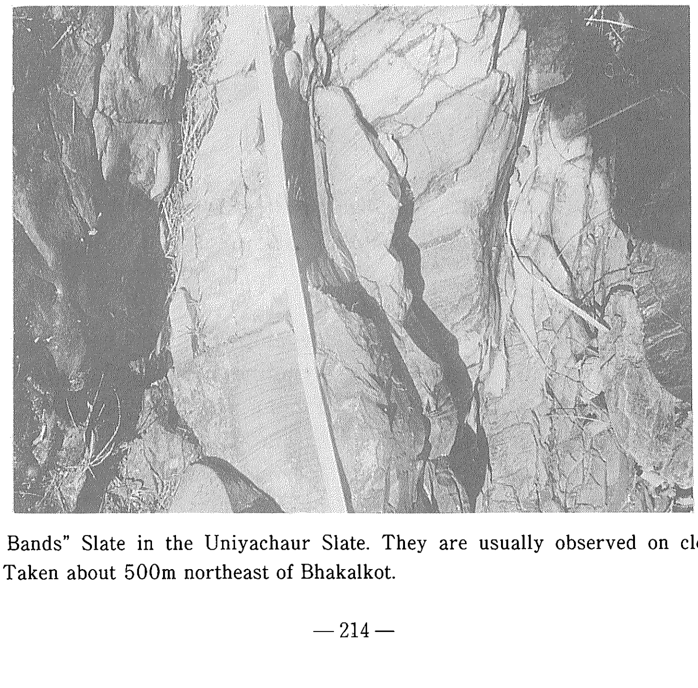

Fig. 8 "Micro-tiger Bands" Slate in the Uniyachaur Slate. They are usually observed on cleavages subparall to laminations. Taken about 500m northeast of Bhakalkot.

Fig. 9 Close-up of the "Micro-tiger Bands" slate. Scale in cm. Taken about 500m northeast of Bhakalkot.

100 to 200 cm thick. The quartzite is traceable as mappable unit for about 20 km from the Tuni Khola in east to north of Putlikhet in west. The total thickness of the unit is approximately 50 m.

The **upper subunit** of the Uniyachour Slate is composed exclusively of slates and phyllitic slates, very scarcely intercalated with sandstones. The color of the slaty rocks is usually black to dark grey and dark green-grey. They are also well-laminated, frequently displaying thin banding characteristic of the "Micro-tiger Bands" slate (Figs. 8 and 9). The slates are ordinarily platy, split into 1 to 2 cm-thick slabs. In general, the slaty rocks of the upper subunit are very similar to the slates in the lower subunit. The upper subunit is approximately 170 to 180 m thick. Consequently, the total thickness of the Uniyachour Slate on the northern wing of the Kheireni syncline is estimated at approximately 330 to 340 m.

A succession similar to the "paraautochthonous" sequence on the wing of the Kheireni syncline can be seen in the uppermost nappe in the syncline as well. In other nappe sheets occur some orthoquartzite bands resembling the middle subunit in the formation. Though some of the quartzite bands have been traced as mappable units, the others are too discontinuous to trace laterally. This is probably due to tectonic disturbances For instance, the middle nappe in the Kheireni syncline contains many orthoquartzite bands near Bhusunpur village, which range in thickness between 15 and 30 m. But none of them could be traced over 1 km because of abrupt disappearance. These laterally discontinuous quartzite bands have been included in the slate subunits on the geologic map.

In general, pelitic rocks in the nappe sheets have been more highly sheared than the equivalents in the "paraautochthonous" sequences, composed largely of phyllitic slates and phyllites. They are dark grey to silver grey and dark to light green in color, exhibiting a silky lustre. The grey-colored varieties contain a large amount of sericite and biotite, whilst the green-colored ones are rich in chlorite. They have been intensely crumpled into microfolds at many places, cut by numerous quartz veins (Fig. 10). The quartz veins are frequently emplaced along the bedding planes of the slaty rocks, widely ranging in thickness from a few mm to 5 m or more. They are occasionally associated with malachite stain and abundantly occur

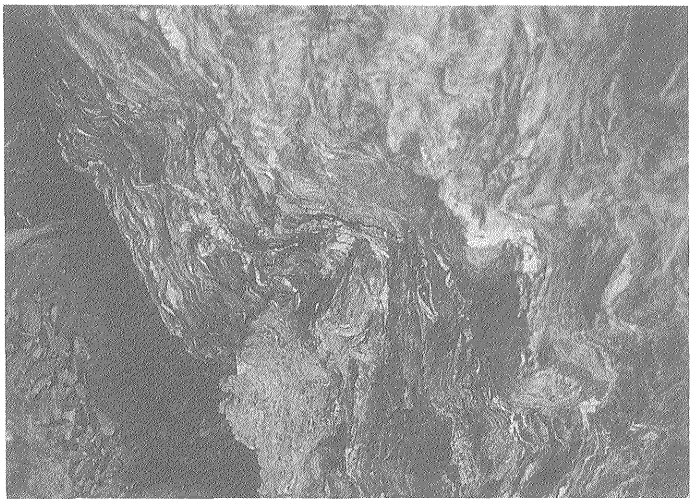

Fig. 10 Highly sheared and crumpled, silver grey to dark grey phyllites with quartz veins (Uniyachaur Slate). Taken 2km west of Gairethok.

east of Kaule village in the area III, forming a rugged ridge.

The Uniyachour Slate is considered to correspond with the Danagaon Phyllites defined by STOCKLIN and BHATTARAI (1977) in Central Nepal.

A. 4 Syangja Formation (Sy)

The formation name was first introduced by HIRAYAMA *et al.* (1981) after the town of Syangja, where the district headquarters of the Syangja District is located. The formation is typically exposed in road cuttings and river cliffs around the town. Despite of the smaller thickess, it is widely traceable in the mapped areas because of the lateral persistence and the characteristic linthofacies, which make the present formation one of the most important markers in the Nawakot Group. It is repeatedly encountered in the present area due to folding and faulting. It is developed in the northern half and the southernmost part of the area I. The formation repeatedly appears throughout the area III, whereas it is restricted to the northern limb and axial part of the Kheireni syncline and the northwestern wing of the Pirung synclinorium in the area II. The present formation is subdivided into three members lithostratigraphically.

The **Lower Quartzite Member (Sy_1)** is most restricted in distribution among the three membres, but it repeatedly occurs in various parts of the mapped areas in close association with the two other members. The unit is well exposed along the bus road south of Syangja, in the upper reaches of the Bhat Khola east of Syangja, and along the main stream of the Dumbribisi Khola in the northwestern margin of the area II.

The present member is composed largely of arkosic quartzite, intercalated with subordinate amounts of slates. The **arkosic quartzite** is usually medium- to thick-bedded, and is very fine- to fine-grained (Fig. 11). The color of the quartzite is commonly dark grey to grey and white, frequently showing a pinkish or greenish tint. The arkosic quartzite is largely composed of quartz and subordinate amounts of feldspar, associated with a minor amount of muscovite (Fig. 14). The quartz grains are commonly subround to subangular, whilst the feldspar grains are mostly subangular in shape. Pink-colored feldspar gives the quartzite a pinkish tint. The arkosic quartzite is intermediate in silica content between the orthoquartzite in

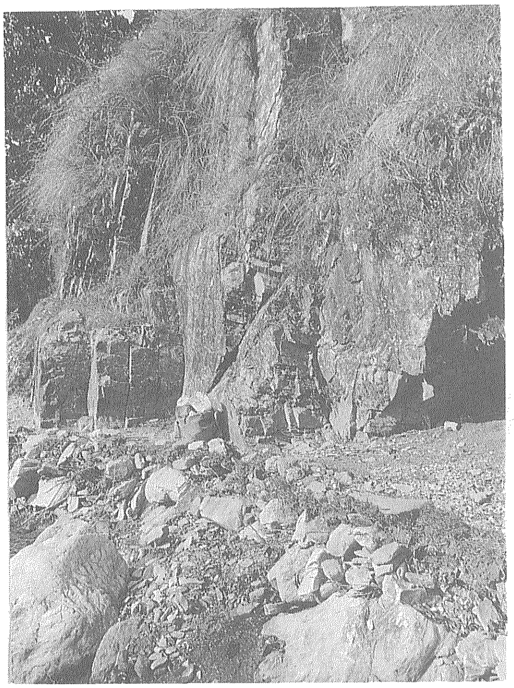

Fig. 11 Medium- to thick-bedded, greenish white arkosic quartzites in the Lower Syangja Formation (Sy_1). Taken in the Bhat Khola.

the Naudanda Quartzite and the dark-colored quartzite in the lower subunit of the Uniyachour Slate, ranging from 83 to 90% (Table 1). The quartzite is generally well-sorted, occasionally showing graded and supposedly asymmetrical wave ripples with bifurcation of the crests. The slipfaces of the ripple marks in the northern part of the area Ⅲ dip southeast. In general, the laminations are rarely found in the quartzite. The slate intercalated in the present member usually varies in thickness between 5 and 30 cm but locally predominates over the quartzite to from some slate-dominant subunits ranging from a few to 10 m thick.

The **slate** is usually of more or less phyllitic nature, frequently showing shaly laminations. The slate is almost identical with the phyllitic slate in the Uniyachour Slate.

The contact between the present member and the underlying Uniyachour Slate, which is observed in a river cliff of the Tuni Khola due south of Mulabari village in the area Ⅲ, is conformable but sharp. The present member is conformably overlain by the Middle Member (Sy_2) and the contacts between them can be observed in the upper reaches of the Bhat Khola. The thickness of the member varies from 60 to 100 m. The present member is considered to be correlative to the Purebesi Quartzite Member in the Nourpul Formation in Central Nepal (STOCKLIN and BHATTARAI, 1977).

The **Middle Member (Sy_2)** of the Syangja Formation has a wider distribution than the Lower Quartzite Member, extending as far south as Chiuri area to the south of the Syangja dome in the area I. It occurs at many places throughout the area Ⅲ, whilst it is distributed in the Kheireni syncline and on the northwestern wing of the Pirung synclinorium in the area Ⅱ. The present unit is well exposed in the river cliffs just north of Syangja and in road cuttings and quarries south of the town.

The present member consists largely of alternating dark grey slates and pink dolomitic rocks, the former predominating over the latter (Fig. 12). The **slates**, when fresh, are dark green-grey in color, changing into light grey sometimes with a greenish or purplish tint in weathered conditions. The weathered parts of the slates frequently show a number of stain-colored laminae, which are composed mainly of quartz grains coated by limonitic films and are probably a leaching product of carbonatic laminae. Individual strata of the slates ordinarily range in thickness from a few mm to 30 cm, rarely exceeding 1 m thick.

The **dolomitic rocks** interbedded with the above-mentioned slates are mostly sandy, widely ranging from quartzitic dolomites to dolomitic quartzites. They react with a dilute HCl solution only after hammering or scratching. They usually vary in thickness between 1 and 5 cm, rarely exceeding 10 cm thick. The color is ordinarily pink to pinkish white in fresh parts, but the decomposed

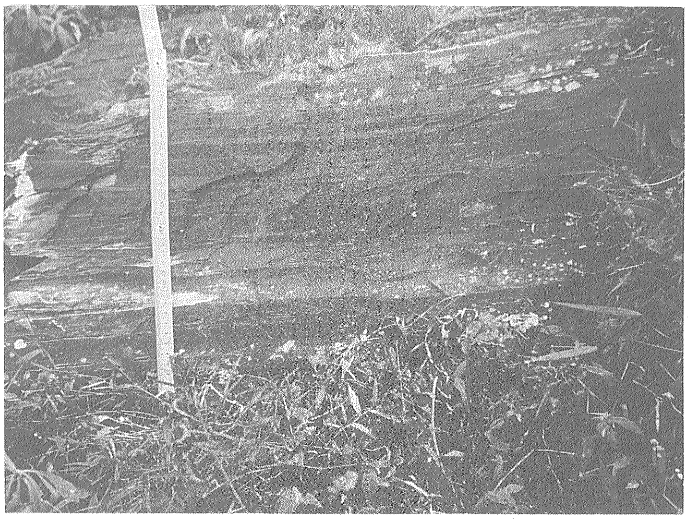

Fig. 12 Thin-bedded alternation of dark grey slate and pink dolomites in the Middle Syangja Formation (Sy_2). Taken in a quarry south of Syangja.

parts have changed to dark brown to yellowish brown quartzites. The remnant quartzites are very porous and consist largely of fine-to medium-grained sands, which are cemented with limonitic materials. These characteristic features provide an excellent criterion for identifying the present member with the limonitic laminae in the slates. Main constituents of the carbonate rocks are dolomite and quartz, associated with less amounts of feldspar and muscovite. Quartz grains in the dolomitic rocks are commonly subangular. The arenaceous dolomites mostly display well-developed gradation, which provides an excellent criterion for the determination of top/bottom of the strata. They sometimes contain small slate clasts. In general, they are poorly laminated, occasionally exhibiting cross-laminations.

The total thickness of the present member is estimated at 70 to 100 m. The Middle Member grades upward into the Upper Pink Dolomite Member by increasing intercalations of carbonate rocks.

The **Upper Pink Dolomite Member (Sy_3)** is one of the most widespread and colorful units in the survey areas, forming an excellent marker horizon with the underlying Middle Member. It is typically exposed in the vicinity of Syangja. In the area I, it is widely distributed not only in the northern half but in the vicinity of the MBT in the southernmost part. It forms part of a nappe in the axial part of the Tansen syncline while it is elongated in a narrow E-W trending belt along the southern limb of the syncline. In the areas II and III, the present member repeatedly appears in close association with the two other members due to folds and faults.

The present member is characterized by thin- to thick-bedded varicolored dolomites intercalated with extremely subordinate amounts of slaty rocks (Fig. 13). The extreme predominance of the dolomites over the slaty rocks is one of the criteria to discriminate the present member from the Middle Member. Regular alternation of colorful dolomites and slates gives rise to a characteristic color-banding in the present member.

The **dolomites** show a variety of colors, such as pink, purplish pink, orange, pale green, white and milky white. They are mostly impure and the impurity contents widely range from 5 to 80% (Tables 2 and 3). The dolomitic rocks frequently show well-developed gradation, with which the carbon-

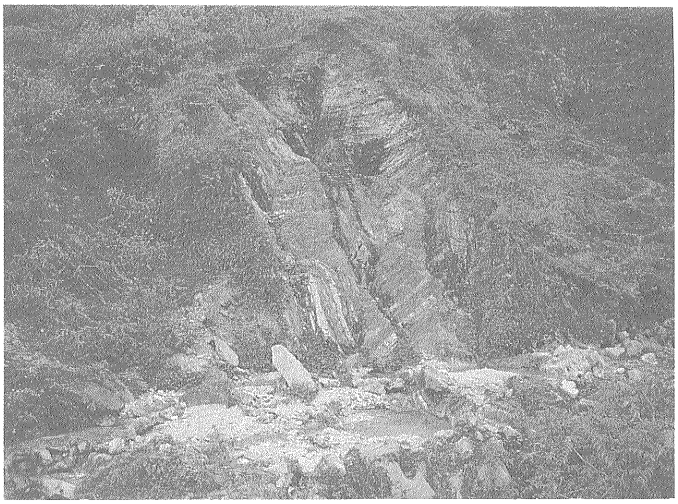

Fig. 13 An outcrop of the Upper Syangia Formation (Sy_3) composed of pink dolomites and white dolomite with subordinate intercalations of slates. Taken east of Niyarabari in the upper reaches of the Bhat Khola.

ate content varies upward systematically. For instance, the samples RT81-120903 (A), (B) and (C) were collected from an about 20-cm-thick bed of pink dolomite, which grades upward from quartzose calcirudite containing round pebbles of pink dolomite (A) through quartzose calcarenite (B) to argillaceous calciludite (C). The carbonate contents decrease upward from 71% to 57%, whereas the silica contents increase from 19% to 34% (Table 2). On the contrary, the samples RT81-121306 (A) and (B), which were taken from a 5-cm-thick bed, decrease in silica content from 71% in dolomitic quartzite at the base (B) to 3.6% in pink calcilutite at the top (A) (Table 2).

The arenaceous dolomites frequently show sedimentary structures reminiscent of the Bouma sequence. Detrital minerals, such as quartz and feldspar, in the dolomitic rocks are mostly fine-grained and less frequently medium- to coarse-grained. They are usually rounded and well-sorted. Further, the arenaceous dolomites frequently contain a lot of rounded pebbles of pink dolomites and dark grey slates. The pebbles are commonly more less flattened and vary from a few mm to 5 cm long.

These dolomitic rocks, especially coarser varieties, have been subjected to leaching of the carbonate components, giving rise to very porous and limonitic-colored quartzites. On the other hand, the finer-grained varieties have frequently survived the decomposition due to less permeability, preserving the original colors. The conspicuous weathering features characterize the present member with a variety of colors in fresh parts. Such intensely weathered parts exhibit much clearer sedimentary structures and gradation than the fresh parts. Asymmetrical ripples with straight crests, which are occasionally found on the carbonate beds, have the slipfaces dipping southeast. As a whole, the carbonate rocks in the present unit are thin-bedded in the lower part, rarely exceeding 5 cm thick, while they thicken upward in the unit, attainig as thick as 1 m or more.

The carbonate rocks in the present member are composed largely of dolomite and quartz with subordinate amounts of feldspar and muscovite (Fig. 14). The contents of the respective minerals widely change from bed to bed as well as from bottom to top within a bed. X-ray diffractograms for some pink dolomites show small peaks of hematite as

Table 2 Chemical compositions of carbonate rocks in the area Ⅲ

Sample No.	Location	Formation name	Loss of ignition %	SiO_2 %	Fe_2O_3 %	Al_2O_3 %	CaO %	MgO %	Dolomite %	Calcite %	Rock name
RT 81-120903(A)	Araudi Kh.	Upper Pink Dolomite Member (Sy_3)	36.55	18.88	1.08	5.38	22.99	14.51	66.75	4.73	calciruditic arenaceous pink dolomite
RT 81-120903(B)			33.43	26.39	1.87	4.63	21.87	12.50	57.50	7.78	calcarenitic arenaceous pink dolomite
RT 81-120903(C)			28.29	33.62	1.01	5.61	19.06	10.88	50.05	6.80	calcilutitic argillaceous pink dolomite
RT 81-121306(A)	Bhat Kh.		45.38	3.61	0.21	2.09	28.88	20.56	94.58	0.21	pink dolomitic calcilutite
RT 81-121306(B)			10.98	71.03	1.00	3.30	6.45	4.43	20.38	0.43	white dolomitic quartzite
RT 81-121001(A)	Araudi Kh.	Darsing Dolomite	29.67	20.54	0.64	1.24	21.03	24.39	62.08	0	grey arenaceous dolomite (parallel-laminated)
RT 81-121001(B)			41.08	12.53	0.79	2.96	25.52	17.94	82.52	0.65	grey argillaceous dolomite (massive)
RT 81-121004			5.63	85.78	Trace	0.36	5.33	2.01	9.25	2.73	grey dolomitic quartzite (parallel-laminated)
RT 81-121004			40.11	14.49	0.29	0.95	26.08	17.74	81.60	2.15	grey argillaceous dolomite (massive)
RT 81-121003			36.96	20.72	0.64	1.20	21.87	17.34	71.86	0	stromatolitic dolomite
RT 81-121101	south of Araudi Kh.		41.99	11.08	0.78	1.01	26.64	18.64	85.74	0.96	microcrystalline argillaceous white dolomite
RT 81-121005	Araudi Kh.	Galyang Slate	43.03	6.10	0.78	1.32	26.64	18.95	87.17	0.13	microcrystalline argillaceous dark grey dolomite
RT 81-121206	south of Araudi Kh.		31.55	26.72	1.14	5.64	21.31	11.89	54.69	8.30	microcrystalline argillaceous black calcitic dolomite
H 81-121101	Bhat Kh.		38.59	8.68	0.50	1.10	46.26	5.64	25.94	59.40	microcrystalline argillaceous black dolomitic limestone

*The contents of dolomite and calcite were calculated on the assumption that all of the MgO and parts of CaO and CO_2 (loss of ignition) are consumed first to form dolomite mineral and then the calcite is formed with the remaining CaO and CO_2.

Table 3 Chemical compositions of carbonate rocks in the area I

Sample No.	Location	Formation name	Loss of Ignition %	Insolubles %	CaO %	MgO %	Dolomite %	Calcite %	Rock name
H 80-121003	Angha Khola	Angha Khola Fm.	36.64	24.82	23.83	16.13	74.20	2.23	argillaceous dolomite whih convolute laminae.
H 81-062601			29.31	35.30	18.79	13.31	60.83	9.51	oolitic orenaceous dolomite.
H 80-122101	Walling	Lower Carbonaceous Slate Member(Gb_1) of Galyong Slates	22.04	53.46	14.86	8.67	39.62	5.01	black dolomitic shale.
H 80-122109	Chhang Chhangdi		35.61	19.38	29.72	10.48	47.90	27.03	grey argillaceus calcitic dolomite
H 81-040203	Dumbribis Kh.	Darsing Dolomite	42.83	7.90	28.04	19.96	89.55	0	columnar stromatolite.
H 80-121809	Churi		37.48	20.12	23.83	17.14	78.33	0	arenaceous dolomite
H 80-120101	Tinau Kh.		24.30	39.50	15.52	10.51	48.03	1.62	argillaceous dolomite.
H 80-120103			33.34	28.52	26.64	11.90	51.02	19.82	argillaceous dolomite with flute casts.
H 80-120402	East of Dumre	Upper Pink Dolomite Member (Sy_3) of Syangja Fm.	30.55	34.50	18.22	12.30	56.21	2.00	grey argillaceous dolomite.
H 80-122805A	West of Syangja		36.90	22.80	26.64	15.12	69.55	8.28	pink arenaceous dolomite.
H 80-122805B			35.08	26.24	28.04	12.10	55.66	19.80	milky white argillaceous dolomite.
H 81-010103			25.48	42.04	19.62	10.00	46.00	10.03	pink arenaceous dolomite.
H 81-010106			22.62	49.34	16.82	10.00	46.00	5.03	pink arenaceous dolomite.

*The contents of the minerals dolomite and calcite were calculated on the assumption that all of the MgO and parts of the CaO and CO_2 (loss of ignition) are consumed first to form dolomite and then the calcite is formed with the remaining CaO and CO_2.

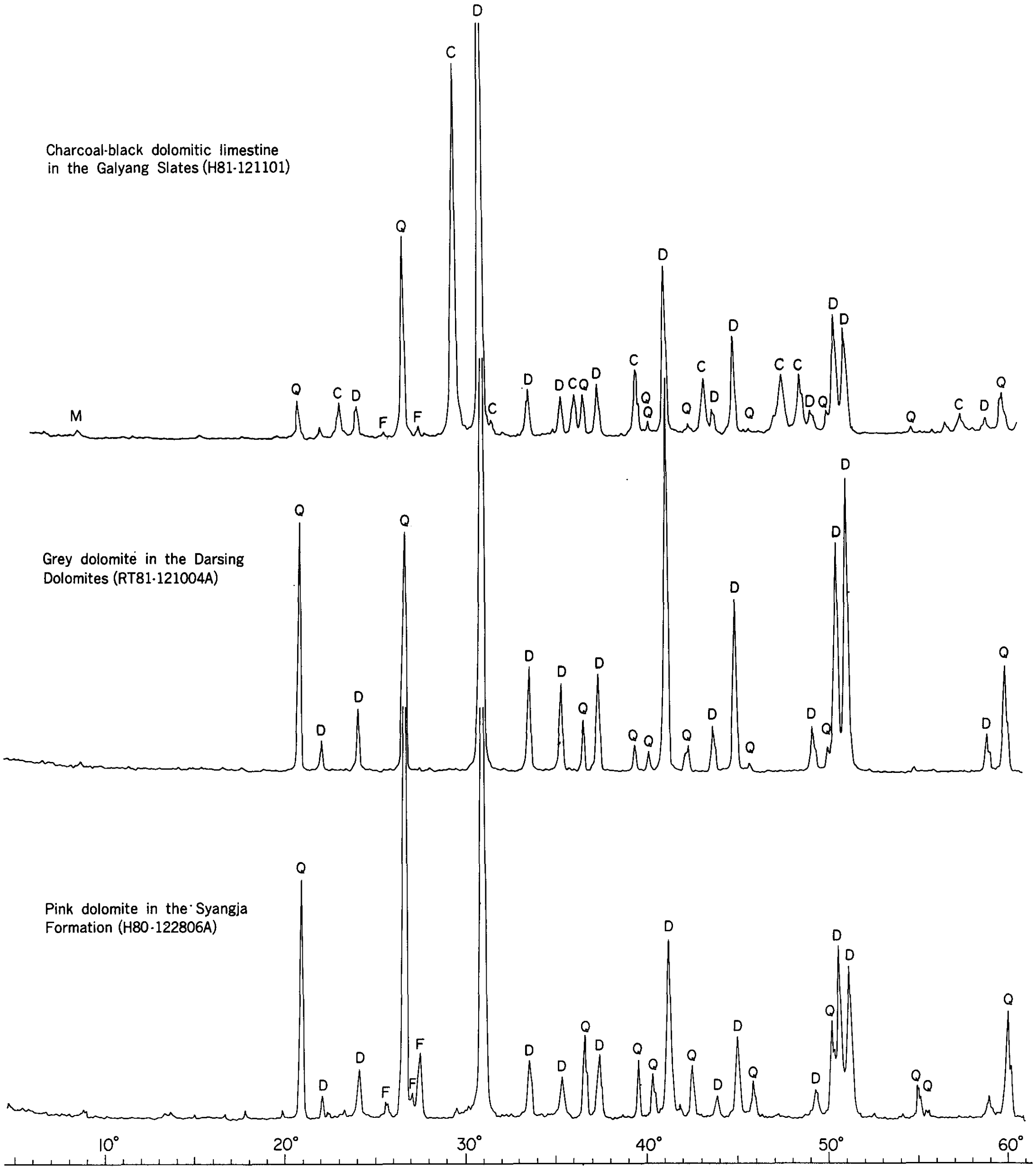

Fig. 14 X-ray diffractograms for carbonates and quartzites characterizing some formations in the Nawakot Group.

well.

The slate intercalations in the present member are usually dark grey in fresh parts, changing to light grey with a greenish or purplish tint in weathered parts. They are thin-bedded throughout the present unit, scarcely exceeding 5 cm thick.

Approaching the overlying Darsing Dolomite, thick-bedded white to white-grey dolomites, which resemble those in the Darsing Dolomite, increasingly appear in the present member. However, the dolomitic rocks in the present unit can be discriminated from those of the Darsing Dolomite by such features as

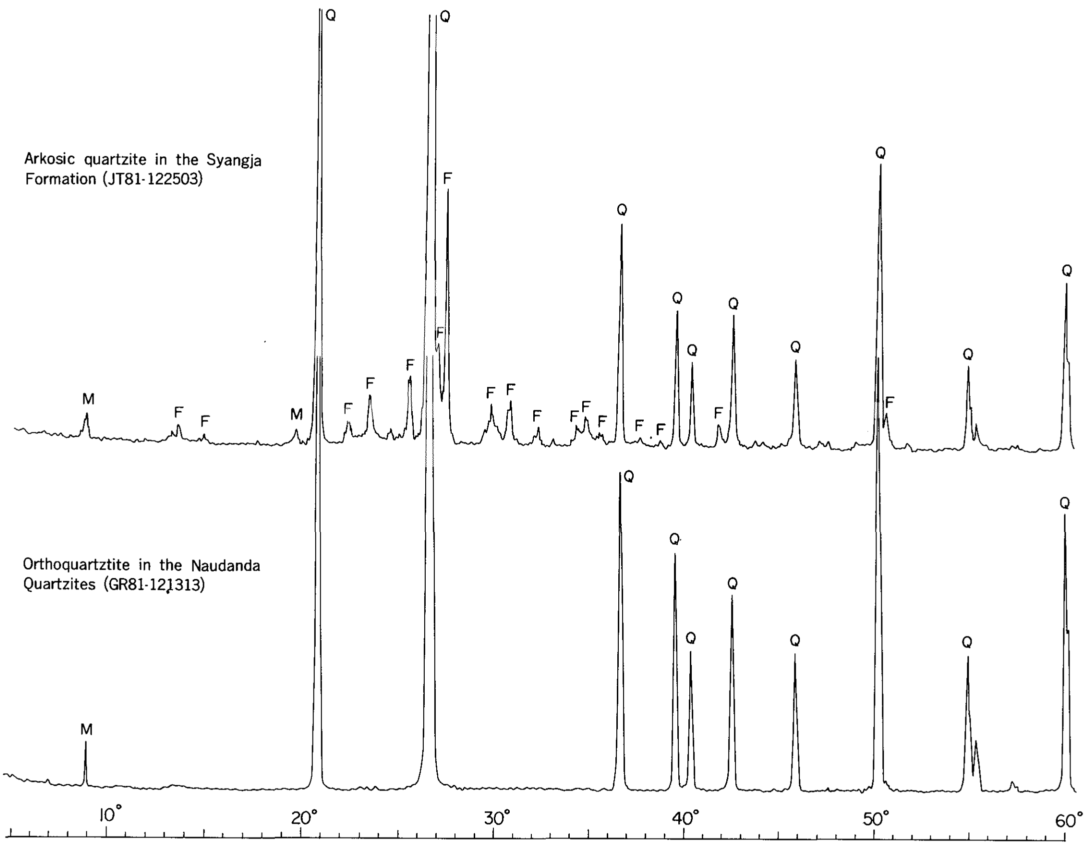

Fig. 14 continued

flatter and clearer stratification, coarser-grained appearance due to clastic impurities and higher crystallinity, and sporadic intercalations of limonitic-colored porous quartzites. The Upper Pink Dolomite Member grades into the Darsing Dolomite with an increase in white to white-grey thick-bedded dolomites at the cost of pink-colored varieties and slate intercalations. The total thickness of the present unit ranges from 70 to 100 m.

The Syangja Formation is considered to be correlative to the Nourpul Formation defined by STOCKLIN and BHATTARAI (1977) by the similar lithofacies and stratigraphic position.

A. 5 Darsing Dolomite (Dr)

The formation name is after the village of Darsing about 8 km southwest of Syangja and was first introduced by HIRAYAMA *et al.* (1981). The formation is widely distributed throughout the survey areas in close association with the Upper Pink Dolomite Member of the Syangja Formation. It is typically exposed along the bus road near Darsing, Chiuri and Kerabari in the area I.

The Darsing Dolomite usually forms high ridges and sheer cliffs. The unit consists largely of grey to dark grey dolomites, very subordinately intercalated with dark grey slates. They are mostly impure and more or less arenaceous or argillaceous, widely ranging in carbonate content from 12% to 90% (Tables 2 and 3). They are dominantly medium- to thick-bedded and less frequently thin-bedded (Fig. 15). They are usually well-stratified, but the bedding is more irregular and undulatory than those of the Upper Pink Dolomite Member (Sy_3).

The dolomitic rocks in the present forma-

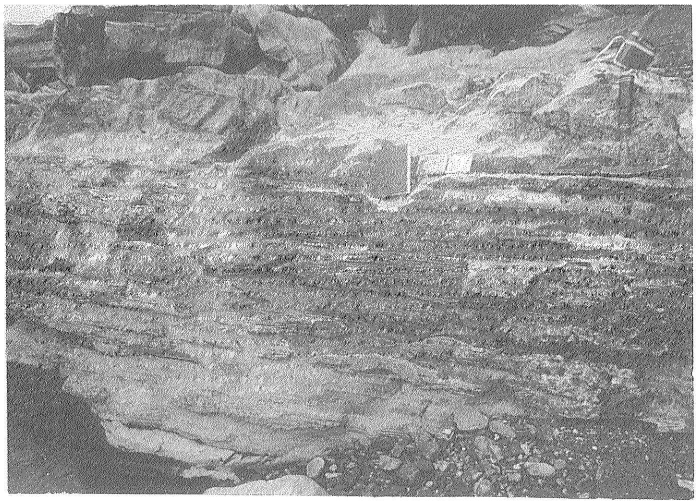

Fig. 15 The Darsing Dolomite (Dr) consisting of alternation of laminated bands (protruded) and massive bands. Taken in the Araudi Khola about 2km southeast of Syangja.

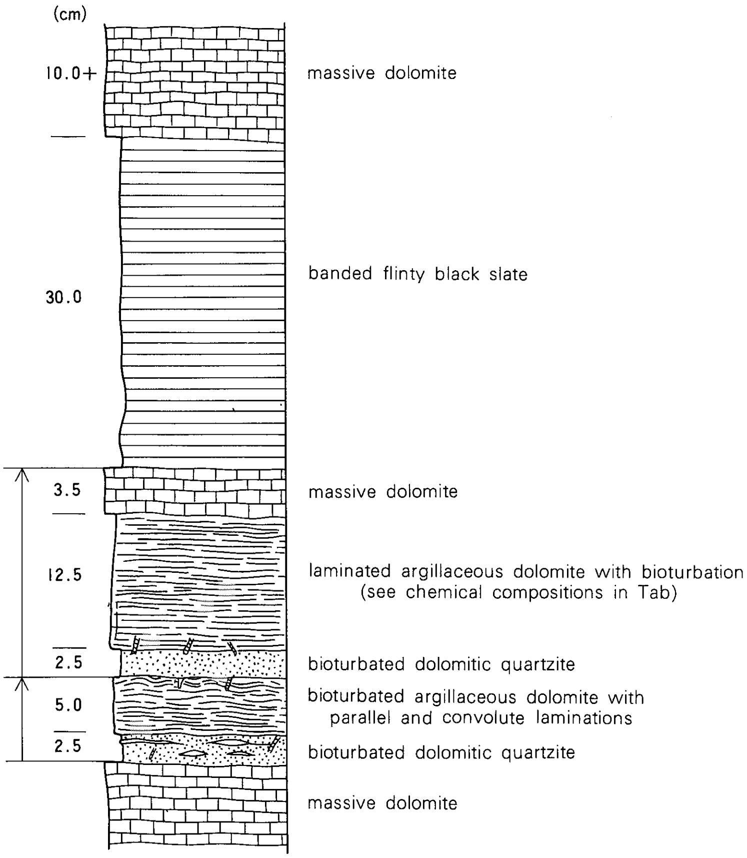

Fig. 16 A rock sequence in the Darsing Dolomite near Kerabari village.

tion frequently show a rhythmic sedimentation. The most complete sequence is composed of dolomitic quartzite at the bottom through parallel-laminated dolomite and massive dense dolomite to black slate on the top (Fig. 16). Frequently, the slate or/and the dolomitic quartzite drop out of the sequence, resulting in a variety of sequences such as alternation of parallel-laminated dolomite and massive dolomite, and others (Fig. 17). The dolomitic quartzite frequently contains clasts of dolomites and slates and shows a fining-upward. The parallel-laminated dolomite is usually a little coarser-grained than the overlying massive dolomite. Thus, the sequence shows a fining-upward as a whole. The laminated parts have been occasionally convoluted. Moreover, flute casts are occasionally found on the bottom of the carbonate beds. These sedimentary features imply a turbiditic sedimentation of the carbonate rocks.

These graded dolomitic rocks increase upward in carbonate content (Table 2). For example, the sample RT81-121001 (A), parallel-laminated arenaceous dolomite, contains 62% of carbonate, whereas the sample RT81-121001 (B), the overlying massive dolomite, contains 83% of carbonate. In the samples RT81-121004 (A) and (B), the laminated dolomitic quartzite (A) and the overlying massive dolomite (B) contain 12% and 84% of carbonate, respectively.

The dolomitic rocks in the present formation distributed to the north of the Kali Gan-

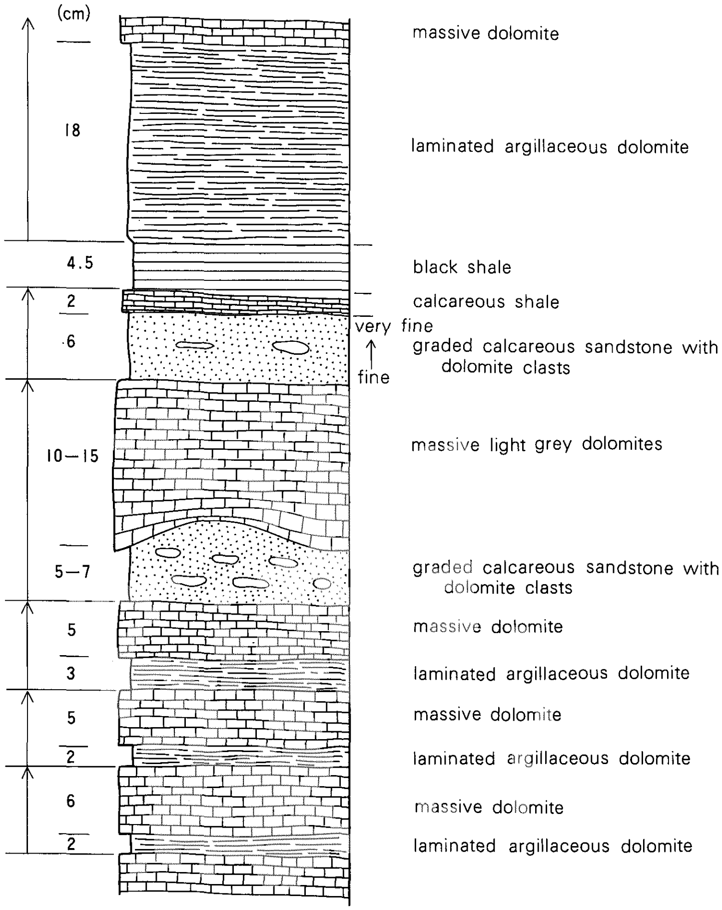

Fig. 17 A rock sequence in the Darsing Dolomite near Kerabari village.

daki River are composed largely of dolomite and quartz, associated with a minor amount of muscovite (Fig. 14). The mixing ratio of quartz and dolomite widely varies from bed to bed as well as from bottom to top in a single layer. However, the dolomites distributed near Kerabari in the southernmost part of the area I contain a small amount of feldspar and chlorite besides dolomite, quartz and muscovite.

The present formation occasionally yields columnar type of stromatolites with broader hemispheroids (Fig. 18). The contact with the overlying Galyang Slate is sharp but conformable. The total thickness of the formation is in order of 800 m. The present formation is considered to be equivalent to the Dhading Dolomite of STOCKLIN and BHATTARAI (1977).

A. 6 Galyang Slate (Gb)

The unit was named after the pass of Galyang southwest of Chiuri village (HIRAYAMA *et al.*, 1981). The typical exposures are observed along the bus road near the Galyang pass. The unit repeatedly appears throughout the areas I and III, whilst it is extensively distributed in the central part of the area II.

The Galyang Slate is lithologically subdivided into two members: the Lower Carbonaceous Slate Member and the Upper Banded Slate Member.

The **Lower Carbonaceous Slate Member (Gb_1)** repeatedly occurs in close association with the underlying Darsing Dolomite throughout the mapped areas. It is represented by characteristic carbonaceous slate and closely associated with less amounts of black-colored carbonates. The **carbonaceous slate** is usually thin- to medium-bedded and generally looks a little thicker-bedded than the slates in the Uniyachour Slate. The carbonaceous slate is characterized by a fresh color of charcoal black to dark grey, resembling the Benighat Slates in Central Nepal (STOCKLIN and BHATTARAI, 1977; STOCKLIN, 1980). The weathered surfaces are often very powdery, so that weeds below the exposures look dirty. Further, the slate is frequently covered with crystalline powder of a white salt. The peculiar fresh color changes to lighter colors, such as light grey, silver-grey, pale green, pinkish white and grey-white in weathered conditions. Slightly weathered parts frequently show fine lamination. The carbon content usually exceeds

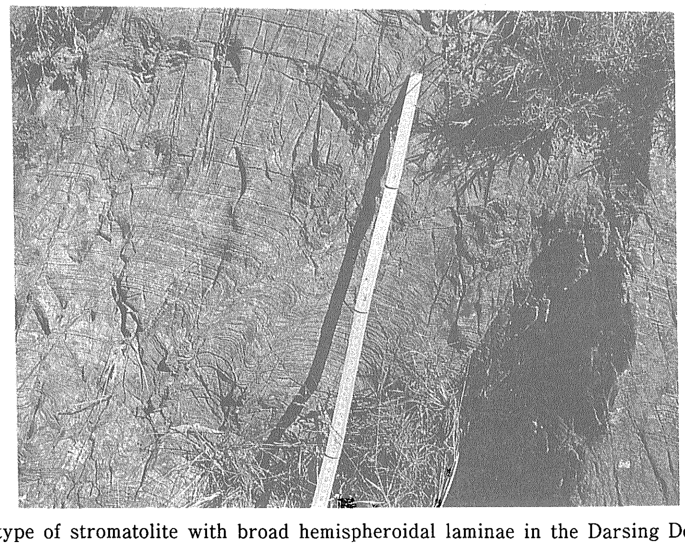

Fig. 18 A cabbage type of stromatolite with broad hemispheroidal laminae in the Darsing Dolomite. Taken in the Araudi Khola southeast of Syangja.

10% and the organic carbon in the slate has been highly graphitized according to the X-ray analysis of the separated carbon. Besides the carbonaceous slate, dark grey slates also occur in the present unit. Though they usually look uniform and massive, the fresh exposures frequently show thin intercalations of the carbonaceous slate.

The **black-colored carbonates** are expressed as bands of calcitic dolomites and calcareous slates (1s) on the geologic maps of the areas I and II (Figs. 2 and 3), but they are included in the Lower Member due to too complicated and irregular distribution in the area III (Fig. 4). They are well exposed along the bus road north of Walling village and between Chiuri and Galyang villages in the area I.

The carbonatic rocks intercalated in the carbonaceous slate are ordinarily thin- to medium-bedded, forming a number of bands ranging from a few m to 30 m or more in thickness. They are mostly microcrystalline, exhibiting a black color similar to that of the carbonaceous slate in fresh parts. Clearer color-bandings can be observed on weathered surfaces. The color-bandings are derived from alternation of finer-grained and coarser-grained carbonates. The former is more argillaceous and show darker colors, such as black and dark grey, whereas the latter is arenaceous and grey to white-grey in color. The arenaceous carbonates form more protruded beds (Fig. 19). These carbonates in the present unit also contain a lot of clastic impurities like the carbonatic rocks in the Syangja Formation and Darsing Dolomite, varying in carbonate content between 63% and 87% (Table 2). However, they are characterized by the coexistence of calcite and dolomite and a high content of carbonaceous matters. They are composed largely of calcite, dolomite and quartz, associated with subordinate amounts of feldspar and muscovite (Fig. 14). Consequently, most of the carbonate rocks in the present unit react vigorously to dilute hydrochloric acid unlike those in the other formations.

On the southern flank of the Syangja dome in the area I, some quartzite beds are intercalated between the top of the Darsing Dolomite and the calcareous dolomite band (1s). The mappable unit (qt) is medium-to thick-bedded, reaching 40 m thick. The color is dominantly white but sometimes pinkish to pale green. The quartzite is mostly dolomitic.

Fig. 19 Thin-bedded black dolomitic limestone in the Galyang Slate. Coarser bands with more clastic impurities are protruded. Note drag-folds. Taken near Chiruwa.

Though no mappable quartzite is developed in the Angha Khola syncline north of Tansen, thin quartzite layers are frequently intercalated in the present member. The present member seems to grade into the Upper Banded Slate Member. The maximum thickness of the unit is estimated at about 600 to 700 m.

The **Upper Banded Slate Member (Sb_2)** is widely distributed in the areas I and II, but has not been found in the area III. The present unit is largely composed of peculiar banded slates nicknamed "Tiger Bands". They exhibit a rhythmical alternation of yellowish white band and dark grey band, each of which varies in thickness between a few mm and 5 cm. Most of the yellowish bands are more or less dolomitic and gives a weak effervescence to a dilute HCl solution only after hammering or scratching. The color bandings are obscured in fresh parts, since both of the bands are dark-colored. However, the yellowish bands are ordinarily devoid of lamination and little coarser-grained than the dark bands, whereas the latter are frequently parallel-laminated. The cleavage planes show a silky lustre and the fragments are sharp-edged.

The contact of the present unit with overlying Angha Khola Formation seems to be gradual and conformable. It is observed in the Angha Khola and Tansen synclines. Towards the top of the member, the dolomitic yellow bands thicken and coarsen to become dolomitic quartzites, finally grading into a quartzite unit (qu_1) at the base of the Angha Khola Formation. The present memer has thrust over the Tertiary fomations in the Tansen syncline. The total thickness is estimated at approximately 1,000 m.

A. 7 Angha Khola Formation (Ag)

The formation was named after the river of Angha Khola, a branch of the Ramdi Khola that joins the Kali Gandaki River near Ramdighat village (HIRAYAMA *et al.*, 1981). It shows excellent exposures along the bus road around Ramdighat and in the vicinity of Nayapati village in the Tansen syncline. The distribution of the present formation is restricted within the Angha Khola and Tansen synclines in the southern part of the area I.

The Angha Khola Formation is divided into two members: the Lower and Upper Members. The **Lower Member** is further subdivided into three subunits. The **lowermost subunit (qu_1)** consists of quartzite, which is very fine- to fine-grained and occasionally feebly dolomitic. The color is commonly light grey. The quartzite is largely thin- to medium-bedded, less frequently thick-bedded. The subunit varies in thickness between 5 and 20 m and is typically exposed along the bus road near Nayapati village in the Tansen syncline. Further, it is traceable in the axial parts of the Tansen and Angha Khola synclines.

The **middle subunit (lm_1)** consists largely of thin-bedded dolomite, conformably overlying the basal quartzite subunit. The color is ordinarily grey, occasionally with pink and green tints. The dolomite frequently displays parallel lamination. The present unit ranges from 10 to 20 m thick and can be traced in the axial part of the Tansen syncline closely associated with the lowermost quartzite subunit. Though it is not found in the axial part of the Angha Khola syncline, it is observed on the northern limb on the northern bank of the Kali Gandaki River.

The **upper subunit (Ag_1)** forms the main body of the Lower Member. The subunit is characterized by thin-bedded alternation of varicolored slates, carbonatic rocks and quartzites. The first predominate over the others. The color of the **slates** ranges from pale green to reddish brown or dark purplish red and dark grey with purple tints. Though the relative abundance of each color varies from place to place, the greenish color seems to be dominant as a whole. In general, they are highly sheared and show a silky lustre on cleavages and bedding planes. They frequently show a phyllitic feature near faults.

The **carbonatic rocks** in the present unit range from dense argillaceous dolomites through quartzitic dolomites to dolomitic quartzites. The color changes from white to pale green and pinkish white. Fining-upward sequences from dolomitic quartzite through quartzitic dolomite to argillaceous dolomite are not uncommon.

The **quartzites** are mostly very fine-grained and thin-bedded. They frequently show flaser beddings, in which cross-laminated sets are separated by thin and discontinuous shale laminae from each other, and wavy beddings that consist of alternation of thin layers of ripple cross-laminated quartzite and slate. The present subunit totals 300 to 400 m thick and is widely distributed in the Tansen syncline. However, it is intensely crumpled into small-scale isoclinal folds and repeatedly appears due to many faults in the Angha Khola syncline.

The **Upper Member** of the Angha Khola Formation is subdivided into four subunits. The **basal subunit ($1m_2$)** is characterized by thick-bedded alternation of argillaceous and arenaceous dolomites with occasional intercalations of slate. The individual beds widely range in thickness from 10 to 100 cm or more, mostly exceeding 30 cm. The color of the dolomitic rocks is grey to light grey.

The **argillaceous dolomites** are mostly parallel-laminated and frequently display convolute laminations reminiscent of stromatolites. The laminae are concentric on the bedding planes, whilst they show hemispheroidal forms in the sections normal to the bedding. There are frequently observed upward-convex hemispheroidal laminae implying inverted strata. The hemispheroids are closely linked with neighbouring ones and vary from 20 to 50 cm in the basal diameter. On the other hand, there occur columnar type of stromatolites in this subunit. They are composed of columnar piles of hemispheroidal laminae 5 to 6 cm across, and adjacent columns are separated from each other by some 1-cm-thick septa. However, these columnar stromatolites are laterally inpersistent, and the hemispheroids are frequently downward-convex, suggesting a slumping deposition. The stromatolite-like convolutions contain about 25% of clastic components, while the columnar stromatolites are almost devoid of clastic matters (Table 3).

The **arenaceous dolomites** interbedded with the argillaceous ones are usually massive and lack distinct gradation The grain size ranges from fine sand to medium sand grade. The sand particles are composed largely of quartz with a subordinate amount of feldspar and lithic fragments. They are mostly subround and float in carbonate cements. Further, some arenaceous dolomites in this subunit contain a lot of ooliths, which have nuclei of quartz and carbonate particles. These carbonate rocks are frequently intercalated with black and pale green slates with a silky lustre. The total thickness of the present subunit varies between 50 and 100 m.

The **middle subunit (Ag_2)** constitutes the main part of the Upper Member consists mainly of thin-bedded varicolored slates with intercalations of pinkish quartzites. The color of the slates varies from purplish red or reddish brown to pale green, the former predominating the latter as a whole. Some of the slates are feebly dolomitic. The basal part of the present subunit consists of thin-bedded alternation of varicolored slates and arenaceous dolomites, so that it is similar to the main constituent of the Lower Member (Ag_1). However, it is differentiated from the latter by the predominance of the purplish slates over the greenish varieties. The present unit is developed in the axial part of the Angha Khola syncline. The total thickness varies between 300 and 400 m.

The **upper subunit (qu_2)** of the Upper Member consists largely of pinkish quartzites, subordinately intercalated with purple and pale green slates. The pinkish quartzites are thin- to thick-bedded. The thin-bedded quartzites seem dominant in the lower part of the subunit. They range from 1 to 10 cm thick and show parallel and cross laminations. Ripple cross-laminations are frequently observed and climbing ripples also are found occasionally. They are very fine- to fine-grained. The intercalated slates are generally 1 to 2 cm thick, rarely exceeding 5 cm thick. At places, however, the varicolored slates predominate over the quartzites.

On the other hand, the **thick-bedded quartzites** often show a planar type of cross-bedding. Each of the cross-bedding sets ranges from 30 to 50 cm thick, separated by thin slate partings. The grain size of the quartzites is fine to medium sand grade. Shale clasts are often contained in thicker beds and have been usually flattened. The upper subunit is developed in the axial part of the Angha Khola syncline and along the main stream of the Kali Gandaki River. The thickness of the upper subunit is estimated at 60 to 75 m.

The **topmost subunit (lm_3)** of the Upper Member is dominated by thick-bedded, dark grey dolomites. The individual beds usually range from 20 to 70 cm thick, occasionally attaining as thick as 3 m. The dolomites are ordinarily parallel-laminated and some of the laminae show a pinkish tint. The topmost subunit is restrictedly developed along a ridge forming the axial part of the Angha Khola syncline and along the Kali Gandaki River. The thickness of the subunit measures approximately 50 m.

A. 8 Ramdighat Formation (Rm)

The formation was named after the village of Ramdight on the Kali Gandaki (Hirayama *et al.*, 1981). It is typically exposed along the bus road around the village. The distribution of the unit is limited to a narrow belt along the Kali Gandaki.

The present formation is the uppermost unit of the Nawakot Group and consists of medium- to thick-bedded alternation of dark grey sandstones, white quartzites and grey slates. The dark grey sandstones and white quartzites widely range in thickness from 5 to 100 cm or more, while the slates vary between 1 and 20 cm thick. In general, the dark grey sandstones greatly predominate the white quartzites. Both of them are largely very fine- to medium-grained. Though the sandstones are mostly massive, some of them show a structural change upward from massive to parallel-laminated. The sand particles are mostly subangular. The direct contact between the present unit and the underlying formation has not been observed but can be inferred conformable. The upper contact is faulted and the total thickness exceeds 750 m.

A. 9 Bungdi Khola Formation (Bk)

The formation was named after the stream of Bungdi Khola, a NE-flowing tributary of the Kali Gandaki River in the area II (Hirayama *et al.*, 1981). The formation is well exposed in the upper reaches of the stream. The distribution is restricted mainly to the northern flank of the Mahabharat Range (Fig. 3). The formation is repeated three times by strike faults, alternating with the Upper Banded Slate Member (Gb_2) of the Galyang Slate. Besides, it is found also in a narrow belt along the Main Boundary Thrust. The present formation is considered to be correlative to the Angha Khola Formation (An) in the area I on the basis of the stratigraphic and structural positions as well as the lithofacies.

The Bungdi Khola Formation is represented by varicolored slates intercalated with subordinate amounts of carbonatic rocks, such as dolomitic quartzites and arenaceous dolomites. The color of the **slates** widely varies from pale green to dark green-grey and red-brown. The alternation of the pale green and red-brown varieties is dominant and their relative abundance differs from place to place. These slates show a silky lustre and are occasionally dolomitic. The **carbonatic intercalations** are also varicolored, showing such various colors as white, pink, grey, pale green, purplish grey and others. The slates interbedded with the carbonatic rocks are commonly thin- to medium-bedded.

Besides, the present formation contains a few units of dark grey to dark green-grey slate, which measure decameters thick. They are splintery and medium-bedded.

There are found a few carbonate units in the formation, the most persistent of which is shown by the letter symbol "li" on the geologic map (Fig. 3). They are composed mainly of thin- to medium-bedded, arenaceous dolomites and dolomitic quartzites with subordinate intercalations of slates. The color of the carbonatic rocks varies from white to sky blue and dark grey. Each of the units ranges from 10 to 100 m thick.

Since the upper limit of the formation is missing due to faulting, the total thickness is unknown but is estimated to exceed 1,300 m.

B. Tansen Group

B. 1 Bhainskati Formation (Bs)

The present formation was named after the river of the Bhainskati Khola (HIRAYAMA *et al.*, 1981), along which it is excellently exposed (Fig. 20). The formation is widely distributed on the both wings of the Tansen syncline and is lithologically subdivided into three members.

The **Lower Pebbly Mudstone Member** (**Bs_1**) consists largely of alternation of dark grey shale and pebbly mudstone bands of the order of decameters to hundreds of meters thick. The **dark grey shale** is usually homogeneous and massive but occasionally parallel-laminated. It is splintery and split into sharp-edged fragments of blade- and pencil-like forms.

The **pebbly mudstone** is composed mainly of dark grey sandy mudstone sparsely scattered with round gravels, occasionally intercalated with gravel lenses. Though it is poorly stratified, the pebbles occasionally show a preferred orientation and imbrication. They suggest the deposition by NE-flowing debris flows. The gravels consist of quartzites, black slates, dark grey dolomitic sandstones, dolomites, and granites. The size usually varies between a few mm and 2 cm or less, sometimes attaining up to 20 cm. Particularly, the gravel lenses are rich in larger pebbles.

Along the Tinau Khola downstream of the junction with the Bhainskati Khola occur a few bands composed of quartzite and con-

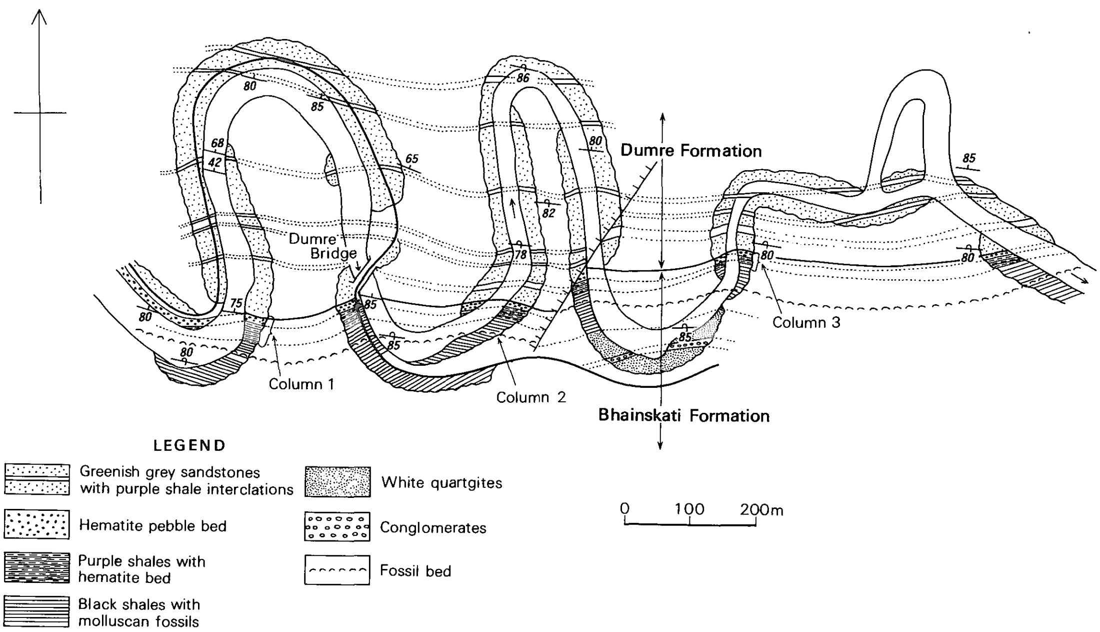

Fig. 20 A route map along the Bhainskati Khola.

glomerate in the present member. Each band measures 20 to 30 m thick and consists largely of interbedded layers of quartzite and conglomerate, subordinately intercalated with thin layers of black shale. Individual layers of the quartzite and conglomerate range from decimeters to meters thick and the former generally predominates over the latter. The boundaries between them are usually sharp and fining-upward sequences from conglomerate to the overlying quartzite have not been observed. The base of the conglomerate beds frequently show large scours. The conglomerate is composed largely of well-rounded pebbles to cobbles of quartzites and granites and angular gravels of black shales. The last are considered to have been derived from the intercalated shale beds. The quartzite interbedded with the conglomerate is white and ranges from very fine sand to fine sand grade in size. It is mostly parallel-laminated and feebly dolomitic. Intercalations of the quartzite and conglomerate increase in thickness and number to the east, grading laterally into the lower part of the Middle Quartzite Member (Bs_2) described below.

The present member yields fossils of small-size *Turritella* at two localities: 1) in a small stream southwest of Dumre village and 2) in the upper reach of the Surangtung Khola 4 km west of Tansen. However, SAKAI (1983), who conducted a detailed regional mapping of the Tansen Group, discovered a bryozoan fossil indicative of the Upper Paleozoic, *Fenestella*, in a scree that is considered to have been derived from the western extension of the present member and attributed it to the Upper Paleozoic fluvioglacial deposits.

The member (Bs_1) on the southern wing of the Tansen syncline is bordered on the Pink Dolomite Member (Sy_3) of the Syangja Formation by the E-W trending Charchare fault, so that the total thickness is unknown. The apparent maximum thickess is estimated at about 1,300 m in the area south of Dumre village, but diminishes abruptly to the east because of lateral facies change into the Quartzite Member (Bs_2). Though the member can be continuously traced from east to west on the northern wing of the Tansen syncline, it is also in fault contact with the Angha Khola Formation. The true thickness is unknown on the northern wing but is estimated to exceed 500 m.

The **Middle Quartzite Member (Bs_2)** of the Bhainskati Formation consists largely of quartzite and dark grey shale, associated with subordinate amounts of conglomerate, ferrugenous sandstone and purple shale. They are well exposed along the Bhainskati Khola and in the vicinity of Tansen.

The **quartzite**, the most dominant constituent of the member, is ordinarily medium- to thick-bedded and rarely thin-bedded. The color is usually white to white-grey. The grain size is commonly very fine to fine grade, occasionally attaining medium grade. The quartz particles are mostly subangular to angular. The thick-bedded quartzite often shows parallel lamination and planar cross-bedding.

The **shale** intercalated in the quartzite is dark grey to dark green-grey. Each shale unit ranges ordinarily from 1 to 10 m thick, showing a scaly splitting. In the shale units, there are found some hematite beds that vary from 20 to 130 cm thick. Pebbly mudstone beds are also intercalated in the shale, and the constituent pebbles are similar to those in the underlying member.

The **conglomerate** intercalations, which are found at places in the quartzite, are 1 to 10 m thick and abruptly change the thickness along the strike. A conglomerate bed exposed in the Bhainskati Khola near Charchare village attains as thick as 10 m but suddenly thins to 1.5 m thick within several hundred meters (Fig. 20). The conglomerate consists largely of subangular to round pebbles and cobbles of white quartzite, dolomite and black shale, associated with a small amount of pebbles of basalt, andesit and dolerite. In the basal part of the conglomerate bed, some huge penecontemporaneous clasts of quartzite attaining as large as 30 cm by 300 cm are found.

The **purple shale** intercalated in the present member ranges in thickness from 30 to 200 cm and occasionally has thin intercalations of grey dolomite. The **ferrugenous sandstone** is usually black to dark brown and fine-grained. The individual beds are commonly a few meters thick, occasionally attaining as thick as 7 m.

While the thickness of the present member totals about 50 m or less to the south of Dumre, it rapidly grows eastward up to 900 m or more to the east of the Tinau Khola by replacing the Lower Pebbly Mudstone Member. On the northeastern wing of the Tansen syncline, the member averages 250 m thick. Though the present unit is extensively developed around Tansen, It has been too highly disturbed by a number of local undulations and faults to establish the stratigraphic succession and total thickness. In the seemingly upper horizon of the member, a few beds, of yolk-colored claysone that is shown by a dotted line on the geologic map (fig. 2) are intercalated in the quartzite and yield some fossils of small pelecypod to the southwest of Tansen.

The **Upper Fossiliferous Shale Member (Bs3)** of the Bhainskati Formation consists largely of fossiliferous shale, capped by a hematite band (hm). The present unit is well exposed along the main stream of the Bhainskati Khola (Fig. 20).

The **shale** is usually thin- to medium-bedded and splits into pencil-shaped or scaly fragments. The color is dark grey to carbon black. The carbon content measures a few % and the organic carbon has been suffered no graphitization. In the shale occur several mollusk-bearing layers, which range from 30 to 60 cm thick. Each of the layers show a sort of gradation, in which shells are densely concentrated at the base and become gradually sparse to the top (Fig. 21). The basal part looks like an argillaceous limestone. The mollusk consists of *Turritella* and some kinds of pelecypod. The fossils of *Turritella* show a preferred orientation, implying a current transportation. Further, these shell-bearing beds contain small pebbles, so that they are indicative of the same transport mechanism as that of pebbly mudstones. Fossils of *Nummulites* have been found in a small stream southwest of Dumre village and in a minor distributary of the Tinau Khola. These fossil-bearing shales are repeated many times by strike faults on the southern wing of the Tansen syncline.

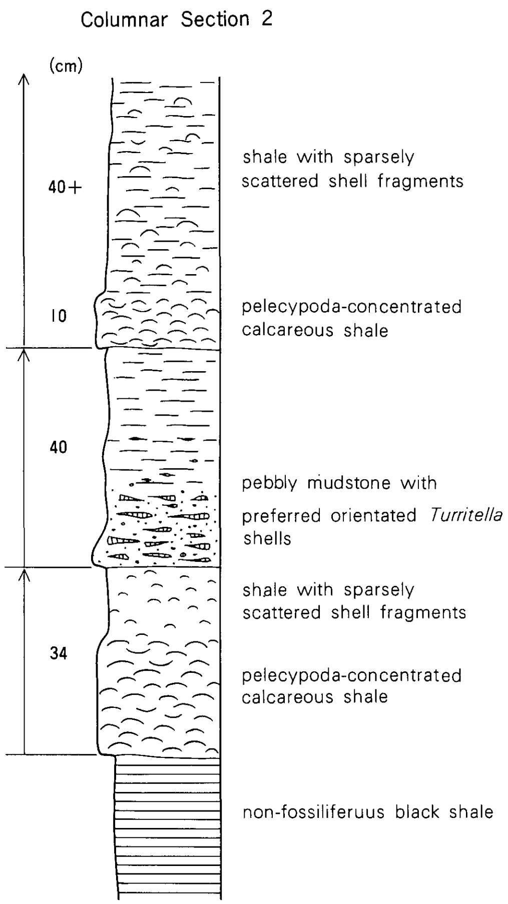

Fig. 21 Gradation in fossil beds in the Bhainskati Formation. For location of the column see Fig. 20.

The **hematite band (hm)**, which marks the top of the present member, consists of a

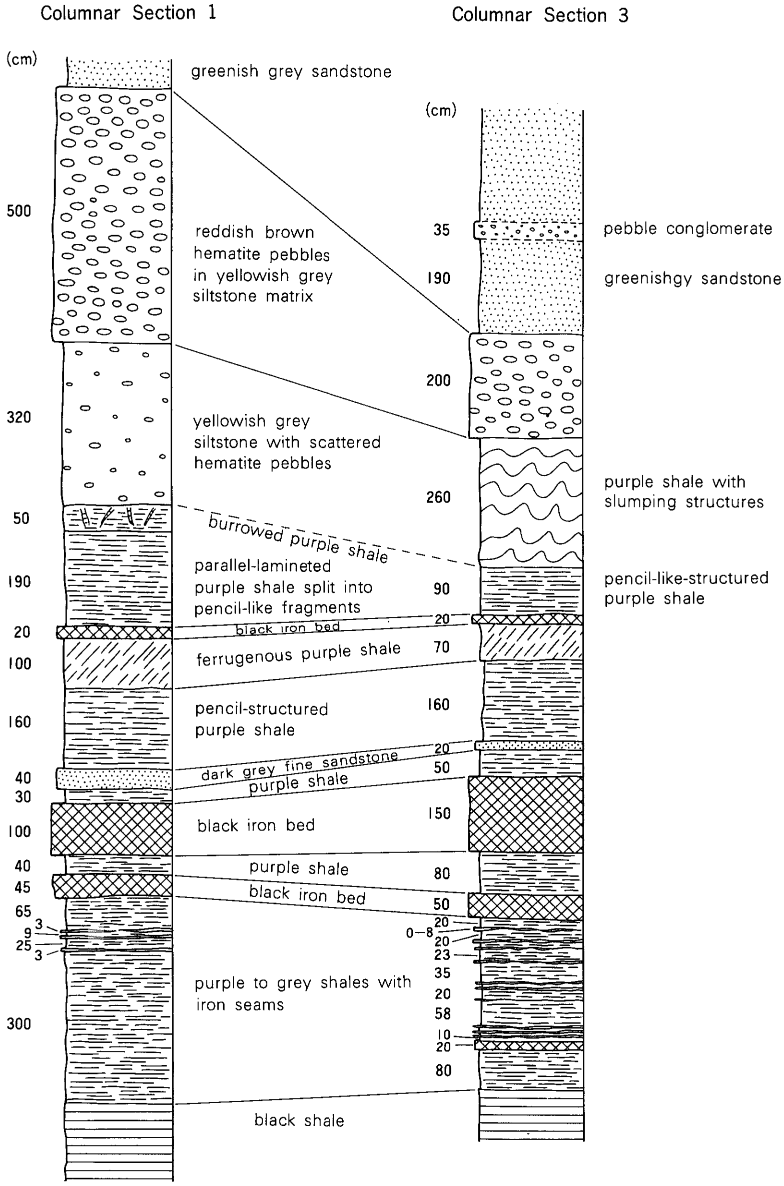

Fig. 22 Columnar sections of the uppermost part (hm) of the Bhainskati Formation. For locations of columns see Fig. 7.

conspicuous alternation of hematite and purple shale, forming an excellent marker-horizon. The purple shale is medium- to thick-bedded, split into pencil-like fragments. The shale is intercalated with a few beds of black-colored compact hematite, the thickest of which attains 150 cm thick. The hematite band is capped by an extremely eye-catching bed composed of hematite pebbles (Fig. 22). It consists of red-brown hematite pebbles scattered in grey to yellow-grey mudstone matrix. The hematite pebbles are mostly sub-round and measure 1 to 4 cm in diameter. The mudstone matrix changes to sandstone at places. The occurrence of the hematite pebbles indicates that they have been derived from the underlying hematite beds by a subaqueous mudflow. The thickness of the hematite pebble bed is extremely variable laterally, changing from 120 to 700 cm for a short distance. Screes derived from the hematite pebble bed are eye-catching enough to predict the exposures upstream for the peculiar color and texture. The marker-horizon including the hematite pebble bed can be traced into the northeastern wing of the Tansen syncline as well. The total thickness of the present member ranges between 50 and 200 m.

B. 2 Dumre Formation (Dm)

The formation name is after the village of Dumre about 7 km south of Tansen (HIRAYAMA *et al.*, 1981). The formation is well exposed along the Bhainskati Khola downstream of Dumre village. It is continuously distributed from the southern wing to northeastern wing of the Tansen syncline.

The Dumre Formation is represented mainly by alternation of sandstone units and shale units, subordinately intercalated with conglomerate. Each of the **sandstone units** ranges from a few meters to 100 m or more thick and is commonly medium- to thick-bedded. The color of the sandstone is dark green-grey. The thicker sandstone ranging from 30 to 300 cm or more are mostly fine-grained and massive to feebly parallel-laminated. However, it is poorly graded. On the other hand, the medium-bedded sandstone occasionally show structural sequences prevailing in turbidites and clearer gradation. On the top surfaces, current-ripples can be observed at places. Some sandstone beds display flute casts on the bottom. Shale partings in the sandstone units are rather rare. The sandstone units, however, are frequently intercalated with conglomerate.

The **conglomerate** is composed primarily of subangular to subround pebbles and cobbles of dolomite, associated with subordinate amounts of shale and hematite pebbles. The dolomite gravels show such a conspicuous limonitic color on the weathered surfaces that they are helpful for the identification of the present formation. The matrix is made of feebly calcareous, green-grey sandstone. The top surface of the conglomerate beds is sharp as the base and shows no gradation into the overlying sandstone. Respective conglomerate beds usually range in thickness between 10 and 200 cm. Thicker beds contain penecontemporaneous sandstone clasts as large as 30 cm by 300 cm and charcoaled woods up to 300 cm long in the basal parts. The woods show a preferred orientation. The current marks including the above-mentioned flute casts and current ripples generally indicate SE- to ESE-flowing currents.

The **shale units** constituting the Dumre Formation range from 1 to 20 m thick. The shale is dominantly reddish purple and subordinately dark grey or pale green. It often shows parallel lamination. The purple and greenish varieties are sometimes calcareous.

The contact with the underlying formation is sharp but conformable. However, the upper limit of the present formation is either faulted or concealed by alluvial sediments. The total thickness exceeds 1,000 m.

B. 3 Damargaon Formation (Dg)

The formation name is after the village of Damargaon on the southern slope of the Mahabharat Range in the area II (Fig. 3). The distribution is restricted to the area between ridge of the Mahabharat Range and the Main Boundary Thrust. The formation is lithologically divided into two members.

The **Lower Black Shale Member (Dg_1)** consists primarily of dark gery to black slaty shale, associated with hematite and white quartzite in the upper part. The **shale** is charcoal black to dark grey and looks massive in fresh parts. But it exhibits black and white laminae on weathered surfaces. The white laminae are slightly coarser-grained than the black ones.

An unit composed of oolitic hematite and white quartzite (hm) is intercalated in the upper part of the formation. The unit is approximately 50 m thick and subdivided into two subunits. The **lower subunit** is dominated by oolitic hematite, interbedded with black to olive-green claystone. The **oolitic hematite** is dark purple-grey and ranges from 10 to 100 cm thick. It shows some evidences indicative of a current deposition, such as current-ripples, imbricated hematite clasts, and faint gradation. The hematite ooliths are mostly 1 to 2 mm across and spheroidal.

The **upper subunit of the hematite band** is composed dominantly of thick-bedded white quartzite, intercalated with black shale. The **white quartzite** is very fine- to fine-grained and well-sorted. The **black shale** is highly bioturbated. The quartzite-dominated upper subunit grades upward through the topmost part of the member, which is composed of alternating black shale and quartzite, into one of the quartzite units (qt_1) composing the Upper Pebbly Mudstone Member.

Since the present member is in fault contact with the underlying Bungdi Khola Formation, the total thickness is unknown but probably exceeds 1,000 m.

The **Upper Pebbly Mudstone Member** consists of alternating pebbly mudstone and quartzite units of the order of decameters to hundreds of meter thick. The **pebbly mudstone units (Dg_2)** consist of massive to poorly stratified pebbly mudstone interbedded with black to dark grey splintery shale. The matrix of the pebbly mudstone is composed mainly of sandy siltstone and occasionally silty sandstone. The gravels scattered in the matrix are mostly a few mm to 3 cm across and subround to subangular. They consist dominantly of white quartzite, black shale, granite, dark grey sandstone etc.

In the present member, four quartzite units (qt_{1-4}) are laterally followed. They are dominated by white to pinkish white quartzite, intercalated with black to dark grey shale. The quartzite is very fine- to fine-grained. It is ordinarily massive and occasionally medium- to thick-bedded. The stratified quartzite exhibits parallel and cross laminations as well as gradation. The total thickness exceeds 700 m. The contact with the overlying Basini Formation is sharp but conformable.

B. 4 Basini Formation (Bn)

The formation was named after the village of Basini on the southern slope of the Mahabharat Range (HIRAYAMA *et al.*, 1981). The distribution is limited to the vicinity of the ridge of the Mahabharat range.

The formation consists mainly of dark grey to dark green-grey sandstone and purple to dark grey shale, the former predominating over the latter. The **sandstone** is largely massive but occasionally medium- to thick-bedded. It sometimes contains dolomitic varieties. The **shale** occurs as subordinate intercalations ranging between 1 and 30 cm thick in the sandstone. The purple shale is more dominant than the dark grey one. Since the upper and lower boundaries of the formation are cut by faults, the total thickness is unknown. It is estimated to be at least 1,700 m.

Correlation

Apart from minor facies variations, both of the areas I and II have very similar lithofacies and stratigraphic successions despite a distance ranging from 20 to 40 km. Particularly, the lithofacies and successions from the Naudanda Quartzite to the Galyang Slate are almost identical in the both areas, though the Uniyachour Slate in the area II is more highly sheared than the counterpart in the area I. Accordingly, the same formation names have been applied to the both areas (Table 4).

Though the Angha Khola Formation in the area I and the Bungdi Khola Formation in the area II slightly differ from each other in lithofacies and successions, both of the formations not only have nearly identical major constituents but occur in a highly-disturbed zone, which extends along the Kali Gandaki River subparallel to the general trend and is sandwiched between the widespread Galyang Slate in the north and the

Table 4 Correlation between Tansen-Syangja, Kheireni-Basini, and Muglin areas

Age-Group \ Area	TANSEN – SYANGJA	KHEIRENI – BASINI	MUGLIN – MALEKHU
TANSEN Gr. (Paleogene)	Dumre Formation	Basini Formation	Nappe of Kathmandu Complex
	Bhainskati Formation	Damargaon Formation	
NAWAKOT Group (Up.Precambrian)	Ramdighat Formation		Nappe ? Robang Phyllites
	Angha Khola Formation	Bungdi Khola Formation	Malekhu Limestone Thrust ?
	Galyang Slate	Galyang Slate	Benighat Slates Disconformity ?
	Darsing Dolomite	Darsing Dolomite	Dhading Dolomite
	Syangja Formation	Syangja Formation	Nourpul Formation
	Uniyachaur Slate	Uniyachaur Slate	Dandagaon Phyllites
	Naudanda Quartzite	Naudanda Quartzite	Fagfog Quartzite
	Kuncha Formation	Kuncha Formation	Kuncha Formation

Tansen Group in the south. Further, both of them conformably overlie the peculiar banded slate ("Tiger Bands") of the Galyang Slate. Accordingly, they are considered to be correlative with each other.

Though the stratigraphic relation between the hematite beds and the pebbly mudstone is reverse in the Bhainskati and Damargaon formations, the similarity of the main componets is sufficient to correlate the both units. The Dumre Formation in the area I and the Basini Formation in the area II are almost identical to each other in lithofacies and stratigraphic position.

The stratigraphy of the Nawakot Group in the Muglin area along the Narayani River, which is located about 70 km east of the area II, was established by STOCKLIN and BHATTARAI (1977, 1980) and STOCKLIN (1980). The lithofacies and stratigraphic successions are amazingly coincident with those of the present area except some minor differences discussed below. The Kuncha Formation, the Naudanda Quartzite, the Uniyachour Slate, the Syangja Formation, the Darsing Dolomite and the Galyang Slate in the present areas are considered to correspond to the Kuncha Formation, the Fagfog Quartzite, Dundagaon Phyllite, the Nourpul Formation, the Dhading Dolomite and the Benighat Slate in the Muglin area, respectively (Table 4).

The Nawakot Group in the area I, through which the Pokhara-Bhairawa Highway runs, has been repeatedly investigated by many previous workers due to the traffic convenience (GANSSER, 1964; TATER, 1967; HAGEN, 1969; FRANK and FUCHS, 1970; FUCHS and FRANK, 1970; TALALOV, 1972; CPIT, 1973; NANDA, 1973; HASHIMOTO *et al.*, 1973; KAYASTHA, 1977). Their opinions are widely diverse on the stratigraphic successions of the divided units as well as their distribution.

Regardless of such a great difference in stratigraphic interpretations, however, their correlations between different structural units are based upon a common assumption that the slates and dolomites with characteristic colors persist in the same horizon throughout the whole area. The assumption has resulted in one of the greatest differences in interpretation on the stratigraphy of the present area between the previous works and the present survey.

In fact, the Syangja Formation, the Darsing Dolomite and the Galyang Slate are characterized by their peculiar lithofacies, such as the arkosic quartzite, and varicolored dolomites and slates for the first, the thick grey dolomite for the second, the charcoal-black carbonaceous slate and calcitic dolomite for the lower part of the third, and finally the banded slates ("Tiger Bands") for the upper part of the third, respectively. The extremely conspicuous succession formed by the characteristic rocks can be persistently traced across the different folds on the northern side of the Kali Gandaki River in the mapped areas. Furthermore, the same succession is traceable as far as the Muglin area investigated by STOCKLIN and BHATTARAI (1977, 1980).

However, the peculiar "Tiger Band" slate in the Galyang Slate is conformably overlain by another unit of varicolored slates and dolomites in the Angha Khola and Bungdi Khola Formations on the southern side of the Kali Gandaki River. As a matter of fact, these varicolored rocks are not only similar to the constituents of the Upper Pink Dolomite Member (Sy_3) in the Syangja Formation, but also accompanied with an unit of grey dolomite resmbeling that of the Darsing Dolomite. The apparent resemblance led the previous workers to the correlation between the Angha khola Formation in the south and the Syangja Formation and the Darsing Dolomite in the north. However, the grey dolomite unit in the Angha Khola Formation ($1m_2$) is not merely much thinner than the Darsing Dolomite, but overlain by another unit of varicolored rocks unlike in the northern area, not by the charcoal-black carbonaceous slate (Gb_1). All of the features above-mentioned indicate the existence of two varicolored units sandwiching the Galyang Slate.

As previously stated, the stratigraphic succession from the Kuncha Formation to the Benighat Slate in the Muglin area matches well with that in the present areas. However, the overlying units, such as the Malekhu Limestone and Robang Phyllite, entirely differ in lithofacies from the Angha Khola and Bungdi Khola Formations in the present areas. The geologic map of 72 A/1 toposheet area, the western half of which is coincident with part of the area II, shows the occurrence of a nappe in the eastern part (DIKSHIT, 1983). The nappe occurs on the eastern extension of the axial part of the Pirung synclinorium and consists of a carbonate unit and the overlying green phyllite unit. Thus, the constituents of the nappe are extremely coincident with the Malekhu Limestone and the Robang Phyllite in lithofacies and succession. Accordingly, the assumption that the Malekhu Limestone and the Robang Phyllite form a nappe well explains the difference in lithofacies between the sequence overlying the Galyang Slate in the present areas and its counterpart in the Muglin area. Further, the tectonic contact between the Benighat Slate and the overlying units gives a better explanation to the abrupt thickening of the Benighat Slate westward from the Muglin area to the area II and the metamorphic inversion between the Benighat slate and the Robang Phyllite than the conformable relationship by STOCKLIN and BHATTARAI (1977, 1980).

Frank and Fuchs conducted a regional mapping of an extensive area, which includes the area I as the eastern margin, in a scale of 1:100,000 (FRANK and FUCHS , 1970; FUCHS and FRANK , 1970). The stratigraphic concept and formation names established in the Indian Himalayas are applied to their stratigraphic description in Western Nepal. One of the greatest differences in stratigraphic interpretation between the previous works and the present one is on the locationing of the Galyang Slate. The Upper Banded Slate Member (Gb_2) around the type locality of the Galyang Slate is included in the Simla Slate on their geologic map, which is interpreted as the lowermost geosynclinal formation in this region. The Infra Krol Shales, which are composed of "black sulphidic shales and slates with some dark cherty dolomitic layers" and considered to correspond with the Lower Carbonaceous Member (Gb_1), is placed in the lower part of the Krol Dolomite, supposedly the equivalent of the Darsing Dolomite. Further, the Infra Krol Shales are interpreted as a contemporaneous heterotropic facies of the Blaini Formation represented by varicolored sediments reminiscent of the Syangja Formation.

Such a great difference in views on the stratigraphy despite of the existence of some remarkable sediments is attributable to the extremely complicated structures, especially a number of thrusts subparallel to the stratification. Additionally, the pelitic rocks, which are poorer in mineralogical and mesoscopic features than the psammitic and carbonatic rocks, make it difficult to attribute their recurrent appearance to a sedimentary cycle or a tectonic repetition. Thus, the establishment of the stratigraphy of the Himalayan area with such complicated structures could be achieved not through a limited number of traverses across the structural trend to make geologic sections, but through the detailed regional mapping to make a reasonable geologic map.

Opinion is widely divided on the age of the Nawakot Group among the workers in the present area because of the absence of index fossils. All attempts to find microfossils in rocks of the present group have been unsuccessful (FRANK and FUCHS, 1970; STOCKLIN and BHATTARAI, 1977, 1980; STOCKLIN, 1980; HIRAYAMA *et al.*, 1981). STOCKLIN and BHATTRAI (1977, 1980) and STOCKLIN (1980) inferred the group ranges in age from Late Precambrian to Lower Paleozoic on the basis of the morphological similarity of the stromatolites, radiometric data, and lithological and stratigraphical comparisons with the Precambrian to Paleozoic sequences in the Indian Himalayas, Pakistan and as far as Afganistan, Iran and Turkey. While GANSSER (1964) suggests a Precambrian to Early Paleozoic age for the stromatolitic dolomites (the Shali Dolomite) in the Inner Carbonate Zone, which coorresponds with the Darsing Dolomite on the northern side of the Kali Gandaki River, he accepts the probability of a younger age ranging from Late Paleozoic to Early Mesozoic for the carbonates in the Outer Carbonate Zone (Krol belt). Though the so-called "Kerabari Dolomite", which is stretched along the MBT, has been correlated with the Darsing Dolomite on the northern side of the Kali Gandaki River on the basis of the lithological and stratigraphic similarities by the present authors, the former differs in mineral composition from the latter, as previously stated. Accordingly, the suggestion by GANSSER (1964) is highly probable.

FRANK and FUCHS (1970) and FUCHS and FRANK (1970) correlated not only the grey dolomites in the Inner and Outer Carbonate Zones for the same reasons as the present authors', but also the varicolored rocks in the Syangja Formation in the north and in the Angha Khola Formation in the south. Further, they are split on the age of the sediments in the Nawakot Group. Frank is in favour of the view that the sediments range from Late Precambrian to Early Paleozoic, whereas Fuchs correlates the grey dolomites in the Darsing Dolomite and the varicolored sediments in the Syangja and Angha Khola Formations with the Upper Paleozoic to Lower Mesozoic formations in the Indian Himalayas and the Salt Range, which are fossiliferous and have similar lithofacies.

Highly persistent lithofacies of the constituent formations and prevalence of such extremely mature sediments as well-sorted quartzites and well-rounded quartz particles in the carbonate rocks indicate a tectonically stable sedimentary environment for the Nawakot Group. Further, abundance of stromatolitic carbonates and hematitic sediments represented by red-colored dolomites and slates suggests a tropical climate condition. Thus, these environmental features are suggestive of the southern side of the Persian Gulf, where stromatolites are thriving at present and the stable Arabian Platform with vast deserts spreads as its provenance. Further, it is extremely improbable that an extensive sedimentary basin with a lot of infertile carbonate coexisted next to the Tethys Sea, which are full of various fossils ranging from the Paleozoic to the Mesozoic. Therefore, the Precambrian would be the most probable age for the Nawakot Group.

FUCHS and FRANK (1970) reported the occurrence of Jurassic to Cretaceous molluscan fossils in their Tal Formation, which is supposed to be a western extension of the Bhainskati Formation in the Tansen Group by the present authors. SAKAI (1983) attributed the Lower Pebbly Mudstone Member (Bs_1) and the Middle Quartzite Member (Bs_2) of the Bhainskati Formation to the Upper Paleozoic and the Mesozoic, respectively, on the basis of the fossil findings, Further, YOSHIDA and SAKAI (1984) reports a northward migration of the paleolatitudes based upon the paleomagnetic measurements, which range from 67 S for the uppermost part of the Lower Pebbly Mudstone Member of the Bhainskati Formation to 10 S for the top part of the formation.

However, we discovered fossils of *Turritella* in the Lower Pebbly Mudstone Member at two localities, as previously stated. Moreover, the Upper Fossiliferous Shale Member (Bs_3) yields not only similar *Turritella* but pelecypod and *Nummulites* at many places. According to the Chinese Petroleum Investigation Team (1973), *Nummulites* from the Upper Fossiliferous Shale Member is similar to *N.* aff. *atacicus* Leymeire and *N.* cf. *mamille* (FICHTEL and MILL), whilst *Turritella* from the Upper Member resembles *T.* cf. *hollandi* Crossman and Pissarro. They are all regarded as being of Eocene age by them. *Turritella* and *Nummulites* in the Subathu Formation in the Indian Himalayas are considered to range from Early Paleocene to Late Eocene in age (KHANNA and SINGH, 1979; BANERJI and SARASWATI, 1981).

Since the Upper Fossiliferous Shale Member is alternated with the Dumre Formation by a number of highly-inclined strike faults subparallel to the MBT on the southern wing of the Tansen syncline, it is possible that the *Turritella*-bearing bed, which was found in the Lower Pebbly Mudstone Member in a small stream south of Dumre village, has been sandwiched in the *Fenestella*-bearing mudstone by SAKAI (1983) by the strike faults. However, it is difficult to assume a similar occurrence for the *Turritella* fossils in the pebbly mudstone found in the Surangtang Khola west of Tansen. Besides, the *Turritella* beds around the type locality not only display and occurrence reminiscent of pebbly mudstones, but the Upper Fossiliferous Shale Member contains a few of pebbly mudstone beds resembling those in the Lower Pebbly Mudstone Member, as previously mentioned. While the Upper Fossiliferous Shale Member is capped by the hematite band (hm) characterized by hematite deposits and purple shale, the Middle Quartzite Member, which was dated as Mesozic, is also intercalated with ferrugenous sandstone and purple shale. Furthermore, the pebbly mudstone is underlain by the oolitic hematite in the Damargaon Formation in the are II. Based upon the observations indicative of a close relationship of the constituents of each member of the Bhainskati Formation, the authors included these members into a formation and assigned to the Eocene.

Though the Dumre Formation yields no fossils, it is tentatively assigned to the Eocene to Oilgocene by CPIT (1973) and to the Lower Miocene by FRANK and FUCHS (1970) and SAKAI (1983) on the basis of the stratigraphic and lithologic similarities with the dated formations in the Indian Himalayas. Since there has been found no positive evidence on a disconfomity between the Bhaiskati and Dumre Formations, the former's view seems to be preferable.

Geologic structures

The survey areas are characterized primarily by E-W trending folds and block faults and thrusts subparallel to the bedding planes. With the exception of the Syangja dome in the area I, anticlinal structures have been entirely destroyed by longitudinal block faluts and synclinal structures alone have survived the tectonic displacements. In general, strata are gently undulated throughout the whole areas except for the vicinity of the MBT and the E-W trending block faults. Aside from the Angha Khola area, no inverted strata have been found despite of the existence of numerous thrusts.

Moreover, the synclinal axes frequently run along high mountain ridges, and major streams which have deeply dissected the ridges often fail to expose the upper parts of the whole sequences constituting the synclinal structures along the river beds. Consequently, we tried to traverse not only major streams but a number of minor streams leading to such mountain ridges to establish the complete successions of the sedimentary sequences. Particularly, the axial parts of many synclines are gently inclined and less disturbed by faults, so that they provide better chances to observe more complete successions than the highly-inclined and more tectonized limbs. Further, such minor steep streams usually display continuous and fresh exposures. Although these streams have numerous waterfalls, they are mostly accessible. Consequently, it is very efficient to traverse the minor streams to get information on the complete sequences.

Before the survey in the area III in 1981/82 period, the first author had not expected the existence of so many thrusts. Through the field works in the areas I and II, which are elongated across the general trend, he had been convinced that the geologic structures of the Lesser Himalaya could be explained primarily by E-W trending folds, the related longitudinal block faults, and a restricted number of thrusts. Therefore, while we were traversing eastward from Syangja along the highly-inclined northern wing of the Kheireni syncline, the first author attributed the repetition of the same sequences to longitudinal normal faults. But he was compelled to believe the existence of many thrusts after we moved to the suothern wing of the syncline, where the strata are gently undulated. Sequences with the same successions are repeated many times in this area as well. They are concordantly superimposed over each other, and can be traced continuously for a long distance along mountain slopes. The boundaries between the similar sequences are subparallel to contour lines because of the gentle inclination of strata, so that they display too complicated planar configurations to explain the repetition of the similar sequences by highly-inclined block faults.

Since the very contacts between the similar sequences are rarely observed, the repetition of the similar sequences might be attributed to sedimentary cycles. A set of conspicuous lithofacies from the Syangja Formation through the Darsing Dolomite to the Galyang Slate can be extensively recognized not only in the area III but in the northern parts of the areas I and II, as described below. Further, the first author conducted a X-ray diffractometry of about 150 samples collected from the repeated sequences to identify the mineralogical compositions of each lithofacies. The result indicates that each of a few kinds of psammitic and carbonatic rocks, which compose the repeated sequences and have characteristic outlooks, shows an amazingly identical mineral assemblage everywhere. Consequently, it is considered more reasonable to ascribe missing or repetition of some units forming a presumably "complete" sequence to faulting than to cyclic sedimentation or local facies changes.

1. Area I (Tansen-Syangja area)

The Syangja dome is an exceptional anticlinal structure which has been exempted from the complete destrcution by block faults. The dome shows a sort of double-ring structure resulted from a repetition of the same sequence. Though the double-ring structure is interpreted in terms of a complicated system of NE-to NEN-trending and E-W trending faults in Fig. 2, it might be better reinterpreted by thrusts. Many of the E-W trending faults are expressed as lineaments on the air-photos, but the NE- to NEN-trending faults are doubtful. Further detailed field surveys are desirable for the reasonable interpretation on the doubling structure.

The Syangja dome is composed of the rocks from the Uniyachour Slate to the Lower Carbonaceous Slate Member (Gb_1). In the northwestern corner of the present area, the dome is thrust up by the Darung nappe composed of the Naudanda Quartzite and the Kuncha Formation. The Syangja dome is bounded in the south on the Walling syncline by a E-W trending north-downthrown block fault, the Armadi Khola fault. The Darsing Dolomite on the upthrow is in contact with the Lower Galyang Slate (Gb_1) on the downthrow.

The Walling syncline consists primarily of the Darsing Dolomite and the Galyang Slate. It ranges in width from 1 to 3 km and widens eastward. Strata on the both wings of the syncline show exceptionally higher inclinations than those in the adjacent structural units. The boundary with the Chiuri syncline, the southern neighbor, is also marked by a north-downthrown block fault, the Andhi Khola fault. The Andhi Khola fault is one of the greatest faults in the present area, by which the Uniyachour Slate in the Chiuri syncline directly contacts the Galyang Slate in the Walling syncline. The displacement of the Andhi Khola fault is much larger than that of the Armadi Khola fault. The Andhi Khola fault extends east-southeast and appears to increase in displacement in the direction.

The Chiuri syncline is underlain by the sequence from the Uniyachour Slate to the Darsing Dolomite. It averages approximately 1.5 km wide and bounds on the Galyang syncline by the south-downthrown Murlibas fault. The displacement is inferred to be of the same order as that of the Armadi Khola fault and seems to increase to the west.

The Galyang syncline is occupied mainly by the Upper Banded Slate Member (Gb_2) of the Galyang Slate, whilst the Lower Carbonaceous Slate Member (Gb_1) forms the both limbs of the syncline. On the northern limb of the syncline, the Lower Member forms a local anticline. Though the widespread Upper Member is locally undulated, it forms a broad syncline as a whole. The Galyang syncline is bordered on the south by the Angha Khola syncline. The boundary between them is marked by the Kali Gandaki fault, which is a south-downthrown block fault and increases in displacement toward the west.

The Angha Khola syncline has extremely complicated structures and is underlain by a wide range of stratigraphic sequences from the Darsing Dolomite to the Ramdighat Formation, attaining 7 km wide. The well-defined synclinal axis is located close to the southern border, the Muslang Khola fault. Though the repetition of the same sequences on the northern limb has been interpreted by a number of north-downthrown normal faults in the present work, it might be better explained by thrusts. The geologic structure of the Ahgha Khola syncline remains open to a further detailed field work. The Muslang Khola fault, which marks the boundary between the Angha Khola syncline and the Tansen syncline, the southern neighbor, is one of the largest faults in the present area, extending from east to west along the northern flank of the mountain ridge representing the northern margin of the Tansen basin.

The Tansen syncline is a sort of a synclinorium associated with some subordiante folds. While the marginal parts of the syncline are occupied by Tertiary sediments of the Tansen Group, the axial part is occupied by a nappe composed of part of the Nawakot Group. The Tertiary sediments on the northern side of the major axis of the syncline have been complicated by some local folds. A number of highly-inclined strike faults are developed to the south of the nappe, giving rise to the repetition of the Fossiliferous Black Shale Member (Bs_3) of the Bhainskati Formation. Since the Tertiary formation on the southern wing of the syncline is highly inclined, the strike faults are subparallel to the bedding planes of the strata. Accordingly, it is probable that the strike faults, which originated in low-angled thruts, have acquired higher inclinations by a later folding. The southern limb of the Tansen syncline is cut by some transverse faults trending NE to NEN, which transect the strike faults. The Tansen syncline is bordered on the south by the Kerabri syncline. The boundary between them is defined by the Charchare fault, which is a north-downthrown, highly-inclined reverse fault with a great displacement. On the both sides of the fault, the lower part of the Tansen Group contacts directly the Upper Pink Dolomite Member (Sy_3) of the Syangja Formation.

The Kerabari syncline is very tightly folded and consists largely of the Darsing Dolomite. The Main Boundary Thrust defines the southern limit of the Kerabari syncline. The thrust is also highly inclined and looks like a sort of high-angled reverese fault at least near the surface. The Charchare fault and the MBT might have been originally a low-angled thrust, which has been deformed into high-angled thrusts through the younger folding.

Two major nappes have been identified in the area I. The first of them, the Darung nappe, caps the mountain ridge about 5 km west-northwest of Syangja. The nappe is composed of the Naudanda Quartzite and the overlying Kuncha Formation, which are bounded by another thrust. The thrust plane between the Naudanda Quartzite in the hanging wall and the Lower Carbonaceous Slate Member (Gb_1) in the footwall is subparallel to the strata, and can be followed along huge cliffs on the southern flank of the ridge. The carbonaceous slate in the footwall has been partially metamorphosed to green schist near the contact. Though the thrust plane between the Naudanda Quartzite and the overlying Kuncha Formation has not been found, it is inferred to be subparallel to the strata in the footwall and the hanging wall.

The second one, the Tansen nappe, occupies the axial part of the Tansen syncline and forms a two-storeyed nappe like the Darung nappe. It overlies the Eocene sediments of the Tansen Group in the northeastern part, while it covers the Upper Syangja Formation and the Darsing Dolomite in the northwestern and southern parts. The southern margin of the nappe is marked by a E-W trending, high-angled fault, which can be oserved along a minor tributary of the Tinau Khola west of Chitradanda village. The Upper Pink Dolomite Member (Sy_3) and the Darsing Dolomite, which fringe the northwestern and southern parts of the nappe, also seem to form another nappe, though they contact the Tansen Group by highly-inclined faults. Since strata near the contacts are highly-inclined, it is highly probable that these faults have been deformed from low-angled thrusts.

B. 2 Area II (Kheireni-Basini area)

The present area is characterized mainly by WNW trending folds and highly-inclined strike faults. Except for some local anticlines, major anticlines have been destroyed by the strike faults in this area as well. The area II is divided into three structural units from north to south: the Kheireni syncline, the Pirung synclinorium and the Mahabharat syncline. Younger strata appear increasingly toward the south as a whole.

The northern wing of the Kheireni syncline is cut by a few subparallel strike faults, which are expressed as lineaments on the air-photos and lead to repetition of the same stratigraphic units. The syncline is underlain by the sequence between the Uniyachour Slate and the Darsing Dolomite, associated with the Lower Member of the Galyang Slate. The Kheireni syncline is bordered on the south by the Pirung synclinorium. The boundary between them is formed by the Kyangdi Khola fault, which is a high-angled, south-downthrown fault and increases westwards in displacement.

The Pirung synclinorium is a broad synclinal structure with a few local anticlines and plunges to the east as a whole. The synclimorium extends between the Kyangdi Khola and the Kali Gandaki River and is underlain by strata ranging from the Uniyachour Slate to the Lower Carbonaceous Slate Member (Gb_1) of the Galyang Slate. The slate is most widespread and occupies the axial part of the synclinorium. The southern border of the structure is marked by the Alaiche Khola fault which parallels to the general trend of the Kali Gandaki River. The fault is a south-downthrown strike fault.

The southernmost Nahabharat syncline lies between the Alaiche fault and the MBT. The main axis of the syncline runs close to the MBT in the Tansen Group. The northern limb of the syncline is composed mainly of strata from the Upper Banded Slate Member (Gb_2) of the Galyang Slate to the Bungdi Khola Formation in the Nawakot Group, which are repeated by faults and local anticlines. The axial part of the syncline is occupied by the Tansen Group, whilst the Bungdi Khola Formation reappears on the southern limb. Though the repeated appearance of the same stratigraphic untis has been interpreted exclusively in terms of highly-inclined strike faults in the present work, low-angled thrusts also might be responsible for it.

B. 3 Area III (Syangja-Kheireni area)

The geologic structures of the present area have been complicated by E-W trending folds, longitudinal block faults and low-angled thrusts, and subordinately by transverse block faults and minor folds. Most prominent among the major folds is the Kheireni syncline, whose axis runs nearly in a E-W direction throughout the present area and plunges to the east. The eastward plunging of the fold axis is well expressed in a U-shaped distribution of the Uniyachour Slate and the Galyang Slate. On the northern wing of the Kheireni syncline, the Syangja Formation, the best marker in the present area, is repeated four times by thrusts and longitudinal block faults. The longitudinal block faults are well visible as a set of subparllel, sharp linear features on the air-photos.

The northwestern corner of the Kheireni syncline has been modified by a few local folds with a E-W trend. The thrusts and longitudinal block faults on the northern limb of the Kheireni syncline have been cut by several transverse block faults. The transverse faults are occasionally observed along minor streams in the upper reaches of the Bhat and Tuni Kholas.

The southern border of the Kheireni syncline is represented by a longitudinal block fault, the western extension of the Kyangdi Khola fault in the area II, which stretches from the lower reaches of the Kyangdi Khola to the Dagdi Khola. A widespread, wedge-shaped mass of the Darsing Dolomite extends from the lower reach of the Kyangdi Khola to the upper reaches of the Bar and Dagdi Kholas on the southern side of the syncline. The dolomite mass is intercalated with the Galyang Slate around the confluence of the Kyangdi and Bar Kholas and is underlain by the Syangja Formation and then by the Uniyachour Slate, which has thrust over the Galyang Slate in the upper reaches of the Buri and Barah Kholas. Consequently, the large dolomite mass is considered to consist of at least two nappes.

The southwestern corner of the Kheireni syncline is flanked by a eastward plunging anticline, whose core is composed of the Darsing Dolomite. The dolomite is conformably overlain by the above-mentioned Galyang Slate, which is thrust up from place to place by different formations, such as the Uniyachour Slate and the Lower Quartzite Member of the Syangja Formation on the northern wing and the Middle Member of the Syangja Formation on the southern wing.

The anticline is bordered on the south by a E-W trending local syncline, the Gahate syncline, which also consists of several nappe sheets of rocks ranging from the Uniyachour Slate to the Galyang Slate. Along the southern margin of the present area, runs a gently curving block fault, which is considered to be the eastern extension of the Armadi Khola fault in the area I and trends in a NE direction as a whole. The block fault has also destroyed an anticline between the Gahate syncline and the Lamichaur syncline in southwestern corner of the present area. The Lamichaur syncline is located on the eastern extension of the Walling syncline in the area I and consists of the Darsing Dolomite and the Galyang Slate. The syncline is bounded on the south by a NE-trending branch of the Armadi Khola fault. The branch fault and the notheastern part of the Armadi Khola fault are flanked on the south by the southerly-inclined Galyang Slate, which is again thrust up by various horizons of the Syangja Formation and the Darsing Dolomite.

Despite the occurrence of numerous nappes, the rock sequences in each nappe seem to be normally superimposed as far as observed. All criteria available for the top and bottom of strata in the mapped area, such as well-developed gradation in the Middle Member of the Shangja Formation and curvature of stromatolites in the Darsing Dolomite, indicate the normal superposition of the constituent strata in the nappe sheets. Accordingly, the multistoreyed nappes are considered to form a sort of imbrication structures.

Structural development

The collision between the Indian and Eurasian continents is considered to be one of the major factors which have affected the structural development of the Himalayan regions. Based upon an analysis of sefloor spreading in the Indiana Ocean, MOLNAR and TAPPONNIER (1975) attributed a sudden drop to half in the rate of northward drift of the Indian subcontinent near 40 Ma to the India-Eurasia collision. Subsequently, PATRIAT and ACHACHE (1984) determined the detailed motion of the Indian plate since anomaly 32 time (late Upper Cretaceous) to clarify the collision chronology on the basis of more comprehensive data on marine magnetic anomalies in the central Indian Ocean.

They divided the drift history into three phases. The first phase before anomaly 23 (52 Ma) is represented by a northward drifting rate fluctuating between 15 and 25 cm/yr. The second phase between anomaly 23 and anomaly 13 (36 Ma) is characterized by several changes in drift direction and a mean velocity reduced to < 10 cm/yr. The third phase ranging from anomaly 13 to the present is marked by a stable northward migration of the Indian continent with a constant rate of about 4 cm/yr. A sudden velocity drop at anomaly 22 (50 Ma) is correlated to the initial collision between India and Eurasia. After the collision, a crustal shortening of the order of 400 km took place through subduction of Indian continental crust beneath southern Tibet till anomaly 20 time (44 Ma). A further shortening, which totals about 300 km, continued between anomaly 20 (44 Ma) and anomaly 13 (37 Ma). The shortening proceeded mainly through crustal thickening by underthrusting along such major thrusts as the MCT and MBT and internal deformation within the Indian subcontinent. Finally, from the anomaly 13 time to the present, crustal shortening amounting to as much as 1,800 to 1,900 km has been mostly absorbed by block rotation and lateral extrusion along large left-lateral strikeslip faults as proposed by TAPPONNIER *et al.* (1982).

On the basis of a paleomagnetic study on precisely dated Paleocene limestones between the Indus-Tsangpo suture zone and the major Himalayan thrusts, BESSE *et al.* (1984) have obtained a similar collision history. According to them, the limestones, which were deposited at some 2.5° S at 57 Ma, migrated to 6° N around 50 Ma, when an intitial collision took place between the Indian and Eurasian continents. They estimated the subduction along the Tsanpo suture between the initial collision and the termination of the subduction due to bouyancy of the subducted crust around 45 Ma at about 550 km. After the closure of the suture subduction, the motion was transferred southward to the MCT and the MBT, resulting in approximately 400 km of crustal shortening by thrusting along them between 45 and 35 Ma.

Following the collision chronology by PATRIAT and ACHACHE (1984), the time span between the initial collision (50 Ma) and the end of the main thrusting phase in the Indian subcontinent (37 Ma) is coincident with Middle and Late Eocene. Inasmuch as the Tansen nappe has concordantly thrust over the Dumre Formation in the Tansen Group, the chronology suggests the Dumre Formation and its correlatives range from Late Eocene to Earliest Oligocene, and the Tansen nappe occurred mainly in Oligocene when a regional regression took place in the Himalayan regions. The northward drift map by PATRIAT and ACHACHE (1984) shows that the present areas migrated from the equatorial area to 8° N during the second phase, which spans from the initial collision to the end of the main thrusting phase.

Such a tropical condition is consistent with the occurrence of tropical fauna, ferruginous sediments, such as hematitic ooliths and purple shale, and quartzite with a high mineralogic maturity in the Tansen Group. Prevalence of pebbly mudstones in the Bhainskati Formation and of turbiditic sandstones in the Dumre Formation is suggestive of increase in paleoslope gradient of the sedimentary basin, which incurs debris flows and turbidity currents, due to the initiation of the collision. Gravel imbrication in pebbly mudstones in the Bhainskati Formation indicates a southern provenance and a northerly-inclined paleoslope, whereas the paleocurrents responsible for sandstones in the Dumre Formation might imply an initial emergence of a northern provenance.

On the other hand, it is widely accepted that the Oligocene regression throughout the Himalayas is succeeded by the Early Miocene transgression, which deposited red-colored sediments derived from a southern lateritic source in the frontal Himalayan regions (GANSSER, 1964; WADIA, 1975; POWELL and CONAGHAN, 1973). Subsequently, the southerly influx of molasse-like clastics commenced in the Middle Miocene and has formed a thick pile of terrestrial sediments coarsening upward as a reflection of the growing Himalayan ranges. Following the chronology, the Lower Siwalik, which is composed of red shale and quartzose sandstone and implys a southern source, represents the Middle to Upper Miocene, whereas the Middle Siwalik predominated by arkose sandstone indicates the commencement of southward influx of clastics from the growing Himalayas in latest Middle Miocene to Pliocene time.

According to the collision chronology by PATRIAT and ACHACHE (1984), the present areas drifted northward between 8° N and 15° N during the oligocene regression (37-24 Ma). Cosequently, the Western Nepal basin and its provenance, North India, were within a lateritization terrain. However, the present areas moved to some 20° N toward the end of the Early Miocene age (10 Ma) and its southern provenance moved out of the lateritization area. This is consistent with the replacement of red shales in the Lower Siwalik by grey shales in the Middle Siwalik (NAKAJIMA, 1982).

The Upper Siwalik in Western Nepal contains a lot of pebbles derived from the Lesser Himalaya (NAKAJIMA 1982) and has been invloved in folding with local inversions (TOKUOKA and YOSHIDA, 1984). These indicate that the E-W folding commenced in latest Pliocene to Early Pleistocene time with the uplift of the Lesser Himalaya and continued till after the deposition of the Siwalik Formation. Inasmuch as the longitudinal block faults subparallel to the E-W folds and the transverse faults cutting the former are developed in the Siwalik Formation, the block faulting is supposed to have occurred mainly in the Pleistocene.

Summary

1) The survey areas are underlain exclusively by a thick sequence of sedimentary rocks, which is divided into the Nawakot Group probably of Precambrian age and the Tansen Group deposited mainly in the Eocene.

2) The Nawakot Group consists of pelitic, psammitic and carbonatic metasediments and is subdivided into the following eight formations in ascending order: a) the Kuncha Formation represented by alternating gritty phyllite and phyllite; b) the Naudanda Quartzite characterized by orthoquartzite; c) the Uniyachour Slate composed mainly of dark grey to black slate; d) the Syangja Formation, which consists of a combination of such characteristic rocks as arkosic quartzite, purple slate and pink dolomite and forms one of the excellent marker-horizons in the areas; e) the Darsing Dolomite represented by a thick sequence of grey dolomite; f) the Galyang Slate, which is divided into the lower member composed of charcoal-black carbonaceous slate and calcitic dolomite and the upper member represented by banded slate reminiscent of tiger skin; g) the Angha Khola Formation in the area I and the Bungdi Khola Formation in the area II, which consist of a mixture of varicolored slates and dolomites, grey dolomite and quartzite; and h) the Ramdighat Formation consisting of interbedded dark grey sandstone, white quartzite and slate.

3) Despite local reappearance due to folds and faults, the younger formations appear southward as a whole in the present area.

4) The Tansen Group consists largely of psammitic and pelitic rocks and is divided into two formations: a) the Bhainskati Formation in the area I and the Damargaon Formation in the area II, which consist of pebbly mudstone with *Turritella*, quartzite intercalated with purple shale and ferruginous sandstone, and dark grey shale with *Turritella* and *Nummulites*; and b) the Dumre Formation in the area I and the Basini Formation in the area II, which consist largely of alternating green-grey sandstone and purple shale.

5) Geologic structures have been complicated by a number of thrusts resulting in an imbrication structure, E-W trending folds and longitudinal blocks-faults. Most of the anticlinal structures have been destroyed by the longitudianal block-faults.

6) The thrusts commenced to form in the northern area probably from the Middle Eocene and propagated to the southern area throughout the Oligocene. The E-W folding commenced in Latest Pliocene to Early Pleistocene time. The block faulting occurred mainly in the Pleistocene.

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西ネパール，レッサーヒマラヤ南部の地質

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要　旨

今回調査した地域は，ほぼ東西方向のレッサーヒマラヤ帯を南北に横切る２つの細長い地域とその間を結ぶレッサーヒマラヤ帯に平行な地域からなる．これらの地域には厚い堆積岩層が分布し，それはナワコット層群とタンセン層群に分けられる．

ナワコット層群の地質年代は先カンブリア紀後期と推定され，その大半が多少とも変成した泥質岩，砂質岩および炭酸塩岩である．ナワコット層群は，岩相および鉱物組成上の特徴から８つの地層に区分される．

タンセン層群はレッサーヒマラヤ帯の南縁部において主境界衝上断層（MBT）に沿って東西の細長い帯をなして分布する．タンセン層群の堆積岩は古第三紀の化石や鉄質堆積層を含み，泥質および砂質岩を主とし，２つの地層に区分される．

調査地域の地質構造の特徴は，多数の衝上断層や東西方向の褶曲およびブロック断層によって生じた覆瓦構造の発達である．また，背斜構造の多くが縦走性ブロック断層によって破壊されていることもひとつの特徴である．タンセンの南部ではナワコット層群からなる大きなナップがタンセン層群の上に，一見整合的に重なっている．そして，下位のタンセン層群と共にひとつの大きな向斜構造を呈する．これらの事実は，衝上断層の形成はタンセン層群の堆積後，多分漸新世であり，引続いて東西性の褶曲が発達し，最後に縦走性ブロック断層が生じたことを示唆している．

（受付：1986年12月17日；受理：1987年12月３日）