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Lower Palaeozoic Tethys sediments from the Kathmandu Nappe, Phulchauki area, central Nepal

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ABSTRACT

Stratigraphy of the middle to upper part of the Kathmandu Complex around Phulchauki area was examined. Pebbly mudstone of the Tistung Formation, the lowest formation of the Phulchauki Group, was formerly regarded as evidence of the unconformity between the Bhimphedi Group and the overlying Phulchauki Group. It has, however, been elucidated as a debris flow sediment on the basis of its sedimentary structures. Stratigraphically it lies within the Lower part of Tistung Formation. It is also concluded that the Phulchauki and the Bhimphedi groups are conformable as they show lithostratigraphic and structural continuity. Preliminary palaeontological investigation of trilobites yielded from the Godavari Formation, the uppermost part of the Phulchauki Group, indicates that the youngest formation of this complex can be assigned to Late Ordovician in age. On the basis of the geologic age and lithostratigraphy, a new scheme of correlation between the Phulchauki Group and the proximal Tethys sediments distributed in the High Himalaya is proposed.

INTRODUCTION

The Kathmandu Nappe belonginging to one of the Lesser Himalayan Crystalline nappes in Nepal is unique in having the Phulchauki Group with a thick (8,000 m) fossiliferous Tethys sedimentary sequence, overlying the Bhimphedi Group (Fig. 1). One of the problems of the Lesser Himalayan nappes is the stratigraphic relation between the underlying crystalline rocks of the Bhimphedi Group and the overlying Tethys sedimentary sequence. There is also a problem in correlation between the whole sequence of the Phulchauki Group and the rock sequence of the Tethys zone in the north overlying the Higher Himalayan crystalline rocks. Regarding the age of the Phulchauki Group, several previous works exist but lacks detailed palaeontlogical work. To make a more precise correlation of the Phulchauki Group with the proximal Tethys rocks in the High Himalaya, additional fossil studies are needed especially from the Godavari Formation, the uppermost formation of the Phulchauki Group.

In the north, the Tethys sedimentary sequence overlies the Higher Himalayan Crystallines along the South Tibetan Detachment System (Burchfiel et al. 1992; Hodges et al. 1992) (Fig. 1). The stratigraphic and structural similarities between the proximal Tethys sedimentary sequence and the Phulchauki Group, points to the possibility of the presence of the detachment also in the Kathmandu Complex between the Bhimphedi and the Phulchauki groups.

In view of the regional stratigraphical and structural problems in the Kathmandu Complex mentioned above, during the present study the author focussed mainly on the following aspects: i) to clarify the stratigraphic and sedimentological significance of the conglomerate recorded as evidence of the angular unconformity between the Bhimphedi and the Phulchauki groups (Kumar et al. 1978), and the detailed examination of the boundary between the two groups and stratigraphic description of the basal Tistung Formation. ii) to report on the newly collected fossils from the Godavari Formation and to describe the stratigraphy of this formation. iii) to present a stratigraphic correlation scheme between the middle to upper part of the Phulchauki Group and the proximal Tethys sediments distributed in the High Himalaya based on their fossil contents and lithostratigraphic similarity. iv) to evaluate the possibility of the presence of the detachment fault in the Kathmandu Complex, which corresponds to the South Tibetan Detachment System.

GEOLOGIC SETTING

The study area lies around and to the south of Phulchauki area in central Nepal and covers the axial and southern limb of the Mahabharat Synclinorium, where the whole sequence of the Phulchauki Group can be investigated (Fig. 2). Lithostratigraphy of this area was established by Stöcklin (1980), Stöcklin and Bhattarai (1980, 1981). In the present study, an area covering 10 km (N-S) x 5-8 km (E-W) was mapped in detail.

In this area axes of synclines and anticlines are almost parallel and trend in WNW-ESE direction. One of the major syncline axes runs just south of the Phulchauki peak (Fig. 3 and 4). Faults fall into two groups according to their strike, although most of them are inferred ones. Faults of group-1 run almost parallel to the NW trending folds, and the folds of group-2, cut across the faults of group-1 at right or large angles (Fig. 3). The faults of group-1 have steep dips (Fig. 4), and are classified as longitudinal faults by Stöcklin (1980) and Stöcklin and Bhattarai (1980, 1981)

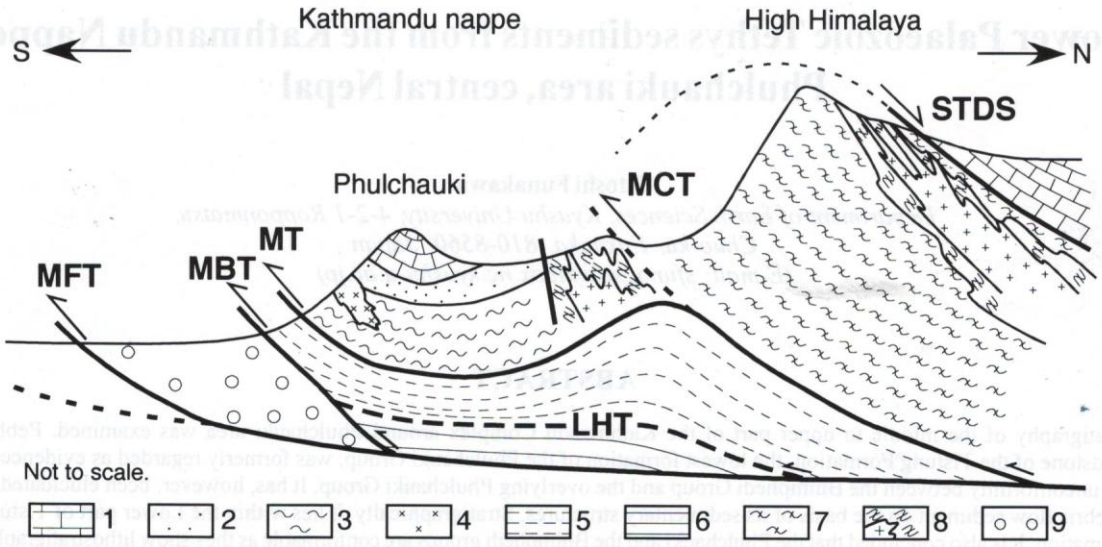

Fig. 1: Schematic north-south geological cross-section of the central Nepal Himalaya. 1–3: Kathmandu Complex comprising Bhimphedi Group below and Phulchauki Group above. 1: Upper Phulchauki Group (Ordovician Tethys sediments dominated by limestone); 2: Lower Phulchauki Group (probable Cambrian Tistung Formation mostly made up of sandstone and siltstone); 3: Bhimphedi Group (Lesser Himalayan Crystallines); 4: Cambro-Ordovician granites intruded into Kathmandu Complex; 5: Nawakot Complex; 6: Lesser Himalayan sediments; 7: Higher Himalayan Crystallines; 8: Injection complex composed of granites and gneisses; 9: Neogene to Quaternary Siwalik sediments; STDS: South Tibetan Detachment System; MCT; Main Central Thrust; MT: Mahabharat Thrust; MBT: Main Boundary Thrust; MFT: Main Frontal Thrust; LHT: Lesser Himalayan Thrust.

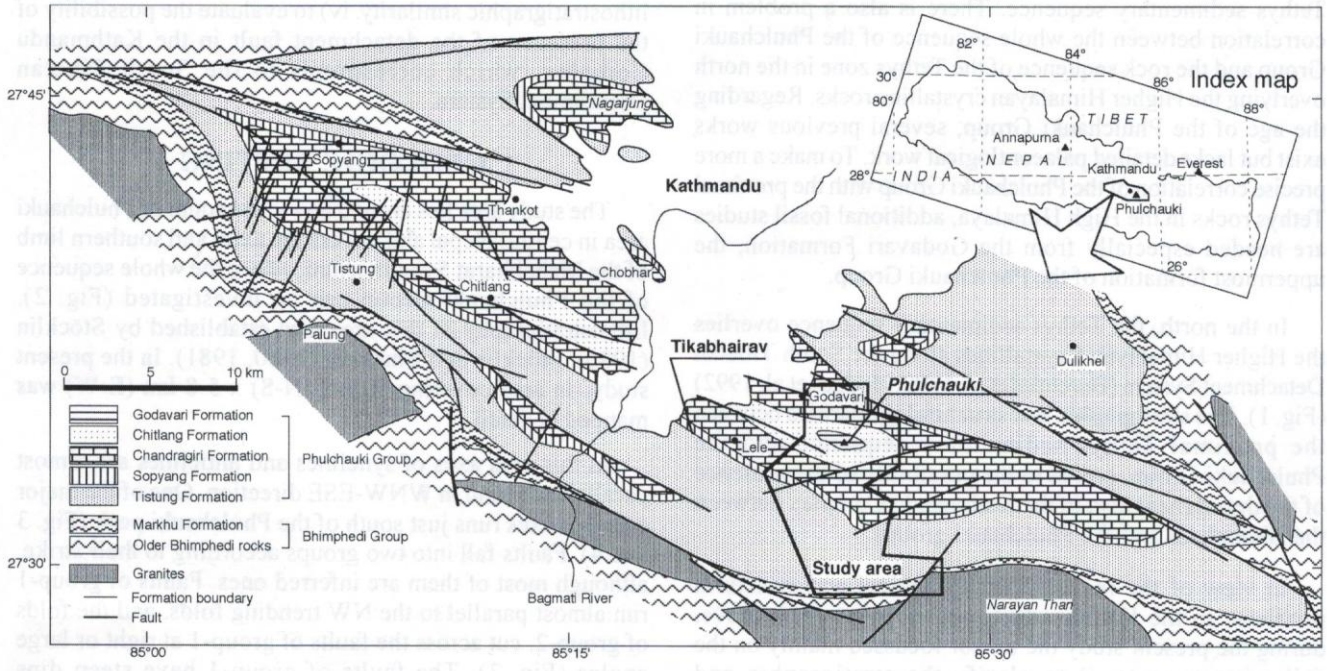

Fig. 2: Simplified geological map of the Kathmandu area and the central Mahabharat Range (redrawn after Stöcklin 1980)

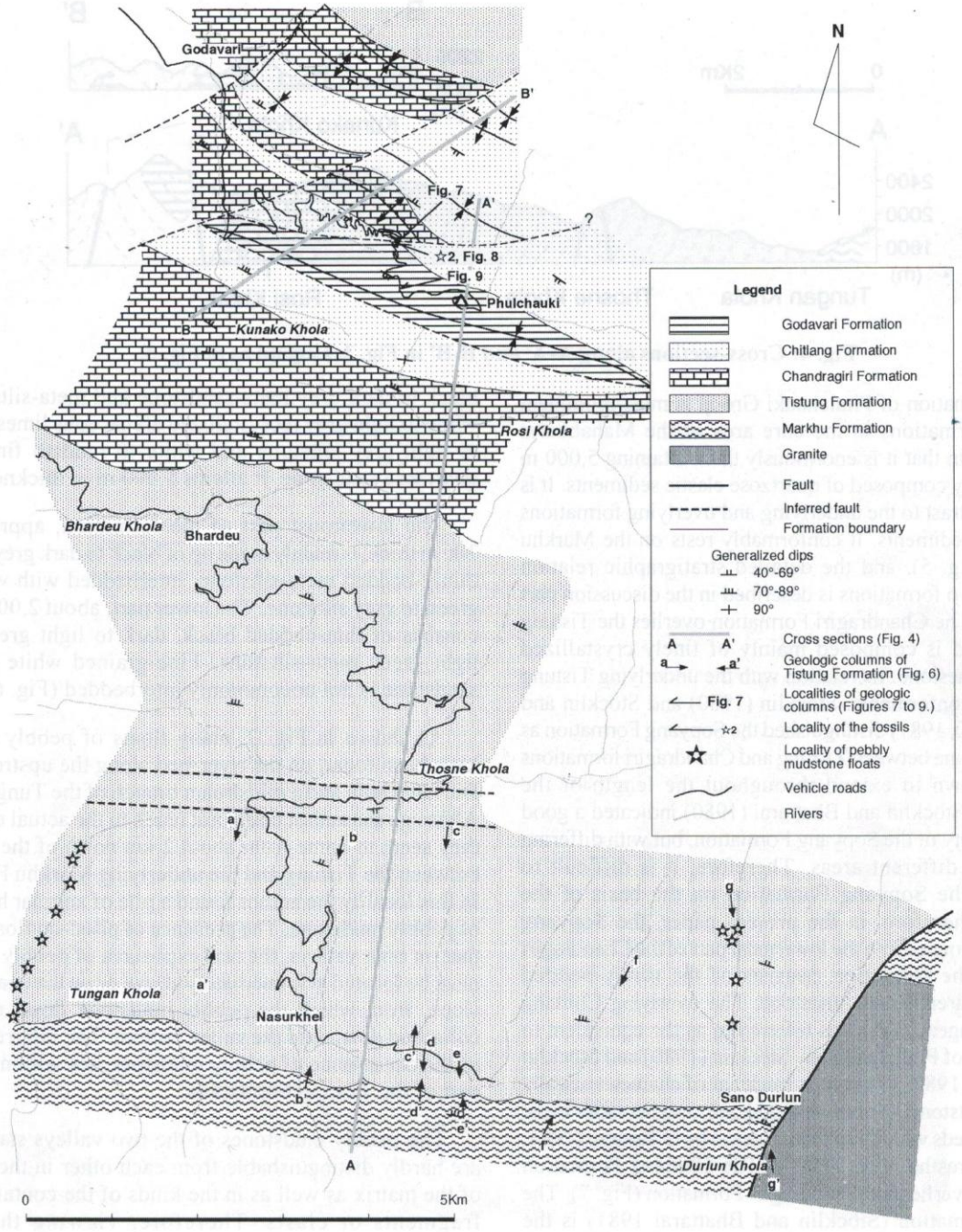

Fig. 3: Geological map of the study area

All the stratigraphic units of the Phulchauki Group, the Tistung, Chandragiri, Chitlang and Godavari formations, are successively exposed forming parallel belts, and in northwardly ascending order in the southern limb of the Mahabharat Synclinorium (Fig. 3). The Godavari Formation, the youngest preserved formation of the Phulchauki Group is distributed in the axial core of the synclinorium. The Markhu Formation, the uppermost formation of the Bhimphedi Group, is distributed in the southern part of the study area, south of the Tungan Khola (Fig. 3).

OUTLINE OF STRATIGRAPHY

Here, only the stratigraphy of the Markhu Formation, the youngest formation of the Bhimphedi Group and the formations of Phulchauki Group are discussed. The Markhu Formation (Stöcklin 1980; Stöcklin and Bhattarai 1980, 1981) is composed of coarsely crystallized arenaceous limestone, calcareous schist and green schist. In the east of the Durlun Khola, the Narayan Than granite (Stöcklin and Bhattarai 1981) intrudes into the Markhu Formation. The Tistung Formation (Stöcklin 1980; Stöcklin and Bhattarai 1980, 1981),

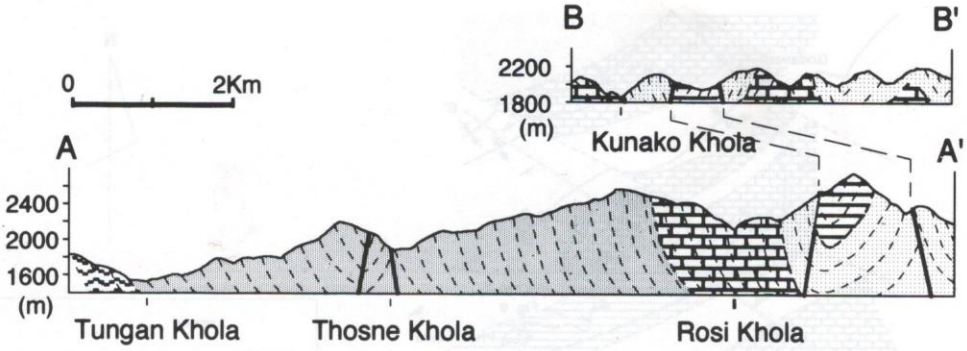

Fig. 4: Cross-sections along A-A' and B-B' in Fig. 3. Legend as in Fig. 3.

the oldest formation of Phulchauki Group is most prominent among the formations in the core area of the Mahabharat Synclinorium in that it is enormously thick attaining 5,000 m and is primarily composed of quartzose clastic sediments. It is in marked contrast to the underlying and overlying formations of carbonate sediments. It conformably rests on the Markhu Formation (Fig. 5), and the detailed stratigraphic relation between the two formations is described in the discussion part of this paper. The Chandragiri Formation overlies the Tistung Formation and is composed mainly of finely crystallized arenaceous limestone. Its relation with the underlying Tistung Formation is conformable. Stöcklin (1980) and Stöcklin and Bhattarai (1980, 1981) distinguished the Sopyang Formation as a transitional zone between Tistung and Chandragiri formations and have shown to extend throughout the length of the synclinorium. Stöcklin and Bhattarai (1980) indicated a good lateral continuity of the Sopyang Formation, but with differing lithofacies in different areas. Therefore, it is difficult to differentiate the Sopyang Formation on the basis of the lithofacies. Therefore, in the present paper, the Sopyang Formation is grouped into the lowermost part of the Chandragiri Formation. The formation consists of the thinly-bedded recrystallized arenaceous limestone. The overlying Chitlang Formation (Hagen 1969) was referred to as the equivalent to "Silurian beds of Phulchauki" by Stöcklin (1980) and Stöcklin and Bhattarai (1980, 1981). It is made up of characteristically dark purple siltstone, quartzose sandstone, and hematite beds. The hematite beds were described in detail by O'Rourke (1961, 1962) and Shrestha et al. (1993). The Chitlang Formation conformably overlies the Chandragiri Formation (Fig. 7). The Godavari Formation (Stöcklin and Bhattarai 1981) is the equivalent to "Top Limestone" by Stöcklin (1980) and "Devonian limestone of Phulchauki" by Stöcklin (1980) and Stöcklin and Bhattarai (1980, 1981), and conformably overlies the Chitlang Formation (Fig. 8). It occupies the uppermost part of the Kathmandu Complex, and is composed of limestone in the lower part and sandstone and siltstone in the upper part.

TISTUNG AND THE GODAVARI FORMATIONS

Tistung Formation

The Tistung Formation is composed of weakly metamorphosed, fine-grained sedimentary rocks comprising black to dark grey meta-sandstone and meta-siltstone, and white to light grey recrystallized arenaceous limestone, grey to light grey siltstone and white to reddish fine-grained quartzose sandstone. It attains 5,000 m in thickness.

The lowermost part of the formation, approximately 200 m thick, is mainly made up of black to dark grey generally thinly-bedded meta-siltstone, interbedded with white, pale green to grey siltstone. The lower part, about 2,000 m thick, consists of thin-bedded black, dark to light grey, dark to light green meta-siltstone. Fine-grained white quartzose sandstone is not uncommonly interbedded (Fig. 6).

As shown in Fig. 3, many floats of pebbly mudstone have been found on the river-bed along the upstream of the Durlun Khola and a midstream branch of the Tungan Khola. Although the author could not reach to the actual exposures, they seem to come from about 2 km north of the boundary between the Tistung and the underlying Markhu Formation. In this locality the author found a pile of angular huge floats of pebbly mudstone. The presence of piled-up floats implies that, in both valleys, the real exposures of pebbly mudstone must be located at immediately above or on the nearby valley slope, from which the pebbly mudstone floats must have collapsed down into the valley bottom. The inferred horizon of the occurrence of pebbly mudstone lies within the lower part of the Tistung Formation.

The pebbly mudstones of the two valleys stated above are hardly distinguishable from each other in the lithology of the matrix as well as in the kinds of the contained rock-fragments or clasts. Therefore, viewing the pebbly mudstones of these valleys collectively, they have a matrix-supported fabric, and are entirely unsorted, having no distinct sedimentary structures such as bedding, lamination, and grading. The matrix, occupying more than 50% of the rock, consists of grey to dark grey mudstone and shows the same lithologic characters as mudstone of the lower part of the Tistung Formation.

The clasts of the pebbly rock are mostly of granule- to pebble-size, rarely of cobble-size, and comprise black mudstone, greenish grey siltstone and white fine-grained quartzose sandstone. Most abundant are black mudstone, and its pebble-sized tabular slabs to granule-sized ellipsoidal chips are densely or sparsely scattered (Plate 1-1). Sandstone

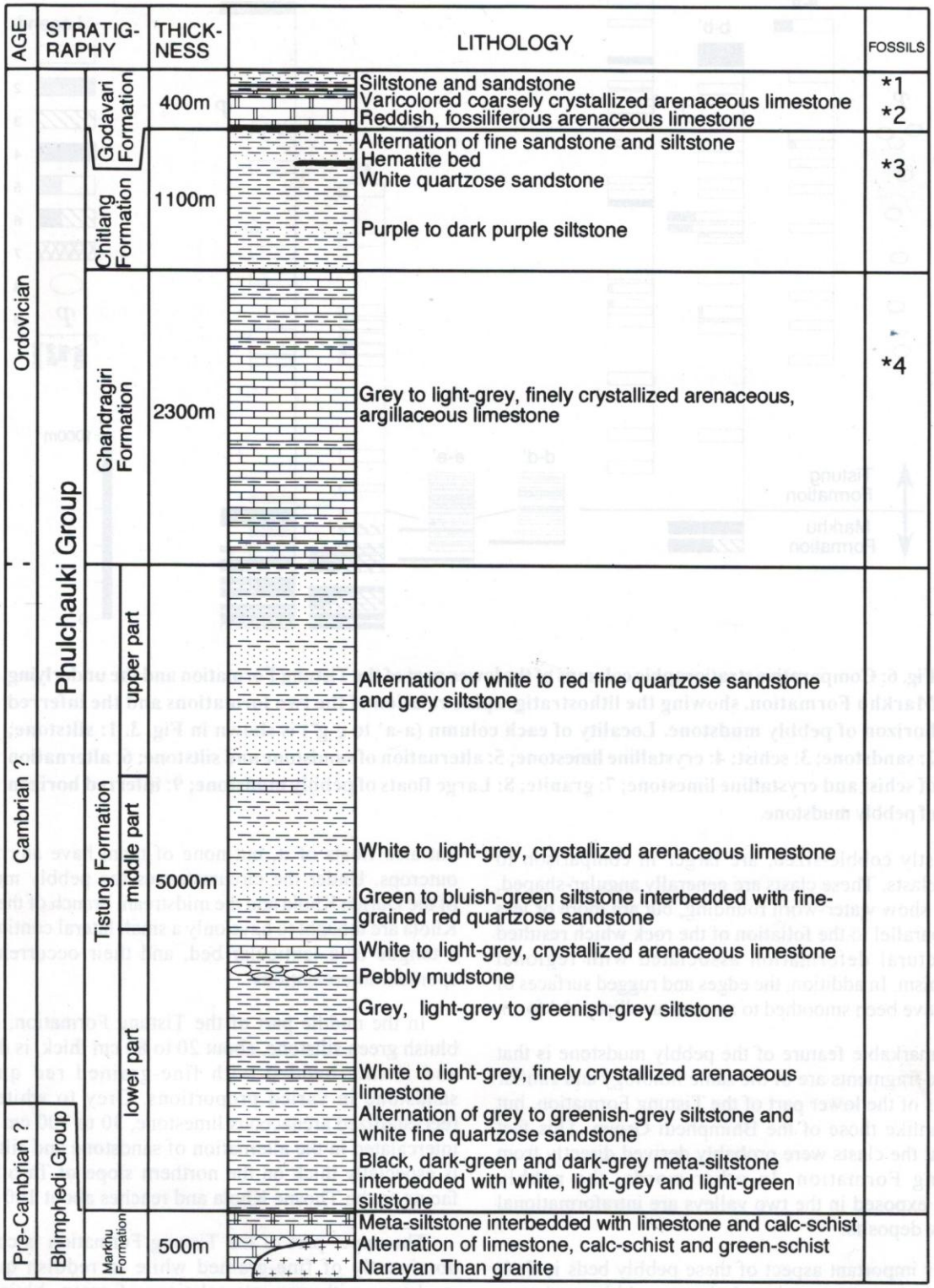

Fig. 5: Generalized columnar section of the Phulchauki Group in the study area. *1-5, Horizons of fossil occurrence. *1: brachiopods, cystoids and crinoids; *2: trilobites, orthoceratid cephalopods, brachiopods and crinoids; *3: trilobites, brachiopods and crinoids; *4: crinoids. Locality *2 is indicated in Fig. 3 and its horizon is shown in Fig. 8.

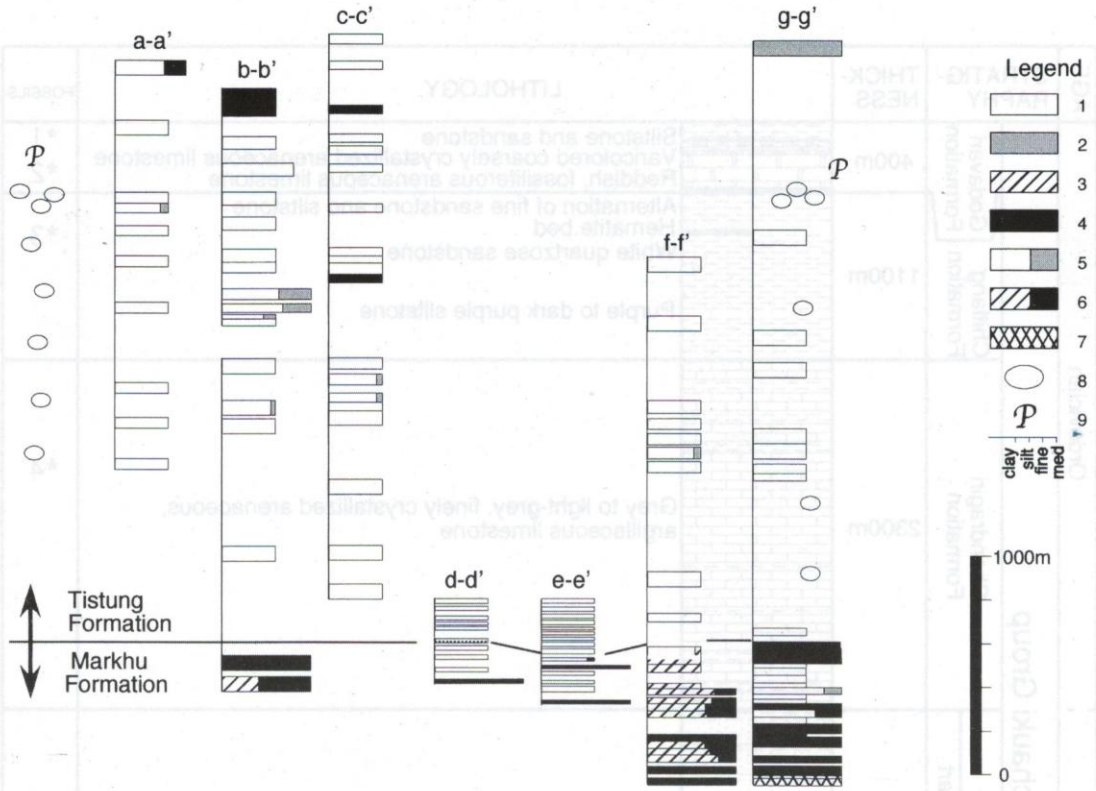

Fig. 6: Comparative stratigraphic columns of the lower part of the Tistung Formation and the underlying Markhu Formation, showing the lithostratigraphic relation of the two formations and the inferred horizon of pebbly mudstone. Locality of each column (a-a' to g-g') is shown in Fig. 3. 1: siltstone; 2: sandstone; 3: schist; 4: crystalline limestone; 5: alternation of sandstone and siltstone; 6: alternation of schist and crystalline limestone; 7: granite; 8: Large floats of pebbly mudstone; 9: inferred horizon of pebbly mudstone.

clasts, mostly cobble-sized, are larger in comparison to mudstone clasts. These clasts are generally angular-shaped, and do not show water-worn rounding, but are more or less stretched parallel to the foliation of the rock which resulted from structural deformation associated with regional metamorphism. In addition, the edges and rugged surfaces of the clasts have been smoothed to assume an ellipsoidal form.

One remarkable feature of the pebbly mudstone is that all the rock-fragments are of the same lithology and similar to the rocks of the lower part of the Tistung Formation, but are quite unlike those of the Bhimphedi Group. This fact implies that the clasts were probably derived directly from the Tistung Formation. In other words, the pebbly mudstones exposed in the two valleys are intraformational debris flow deposits.

Another important aspect of these pebbly beds is their lateral extension. As mentioned above, pebbly mudstone floats have been found in two valleys, which run parallel at 8 km distance from each other. Between these valleys five tributaries of the Tungan Khola also run nearly parallel as seen in Fig. 3. The author investigated these valleys to find out not only outcrops of pebbly mudstone or conglomerate but also floats of it, but none of them have any floats or outcrops. Under the circumstances the pebbly mudstones of the Durlun Khola and the midstream branch of the Tungan Khola are thought to have only a small lateral continuity like a tongue or a lenticular bed, and their occurrence is of sporadic intercalations.

In the middle part of the Tistung Formation, green to bluish green siltstone, about 20 to 80 cm thick, is dominant and is interbedded with fine-grained red quartzose sandstone in varied proportions. Grey to white, finely recrystallized arenaceous limestone, 30 to 100 cm thick, is intercalated in the alternation of sandstone and siltstone. It is especially thick on the northern slope of Taro Kataban facing to the Thosne Khola and reaches about 100 m.

The upper part of the Tistung Formation is composed dominantly of fine-grained white to reddish quartzose sandstone with rare intercalations of green, bluish green, grey to dark grey siltstone. On the polished surfaces of quartzose sandstone, climbing ripples are commonly observed. Cross laminae and parallel laminae are usually well developed in siltstone, and burrows and bioturbation are also common.

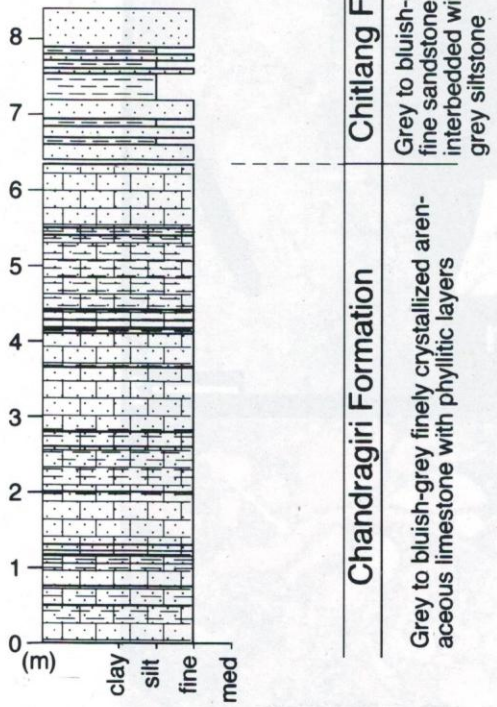

Fig. 7: Columnar section across the boundary between the Chandragiri and the Chitlang Formation at locality shown in Fig. 3. The base of the Chitlang Formation is defined by a 30 cm thick fine-grained bluish grey sandstone.

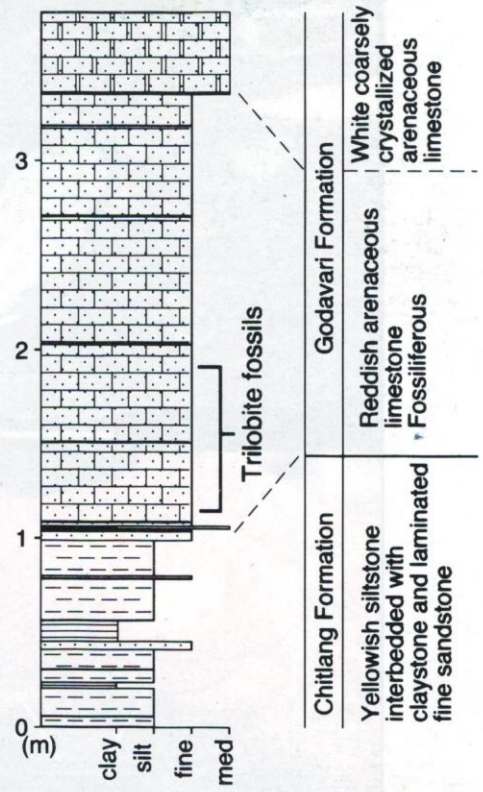

Fig. 8: Columnar section across the boundary between the Chitlang and the Godavari Formation at locality shown in Fig. 3. The base of the Godavari Formation is defined by the first occurrence of reddish fossiliferous limestone. Arrows in figure shows the horizon of occurrence of Ordovician trilobites and other fossils shown in Plate 1.

Godavari Formation

It is the youngest formation of the Phulchauki Group. The Godavari Formation is subdivided into the following four units on the basis of lithofacies: the lower fossiliferous limestone, the middle coarsely crystalline massive limestone, the upper coarsely crystalline well-bedded limestone, and the uppermost sandstone and siltstone.

The lower part is composed of five beds of pinkish to reddish arenaceous limestone (Fig. 8) and yields many kinds of marine invertebrate fossils such as trilobites (Plate 1-3 to 1-5), orthoceratid cephalopods (Plate 1-5), brachiopods, and crinoids. It is conformably overlain by a 40 cm thick, white coarsely crystalline arenaceous limestone bed of the middle part (Fig. 8).

The middle part consists of varicolored (white, pink, red, purple, dark grey, and light grey) coarsely crystalline arenaceous limestone. Crinoid fragments are the main bioclasts. Bedding planes are indistinct. No definite lithofacies change is recognized within this unit.

The upper part comprises phyllitic well-bedded limestones ranging from 20 to 100 cm thick. The color of limestone changes upward from grey through pale green, purple, dark purple to grey. It is rich in crinoid fragments.

The uppermost sandstone and siltstone unit is the youngest strata of the Kathmandu Complex. This unit is made up of light greenish grey siltstone and fine-grained sandstone which weathers to white colour. It has a gradational contact with the underlying unit marked by the alternation of limestone and siltstone. The siltstone has yielded poorly preserved brachiopods (Plate 1-6), cystoids and crinoids. Sandstone is rich in crinoid fragments.

DISCUSSION

Stratigraphic relation between Tistung and Markhu formations

Arita et al. (1973) were the first to report the "conglomerate boulders" from the Tungan Khola. Stöcklin (1980) and Stöcklin and Bhattarai (1981) found many floats of "colored conglomerate" in the alluvium in the lower streams of the Thosne Khola and the Tungan Khola. Stöcklin and Bhattarai (1981) presented a brief description of the conglomerate as "These rocks contain varicolored sub-rounded pebbles,

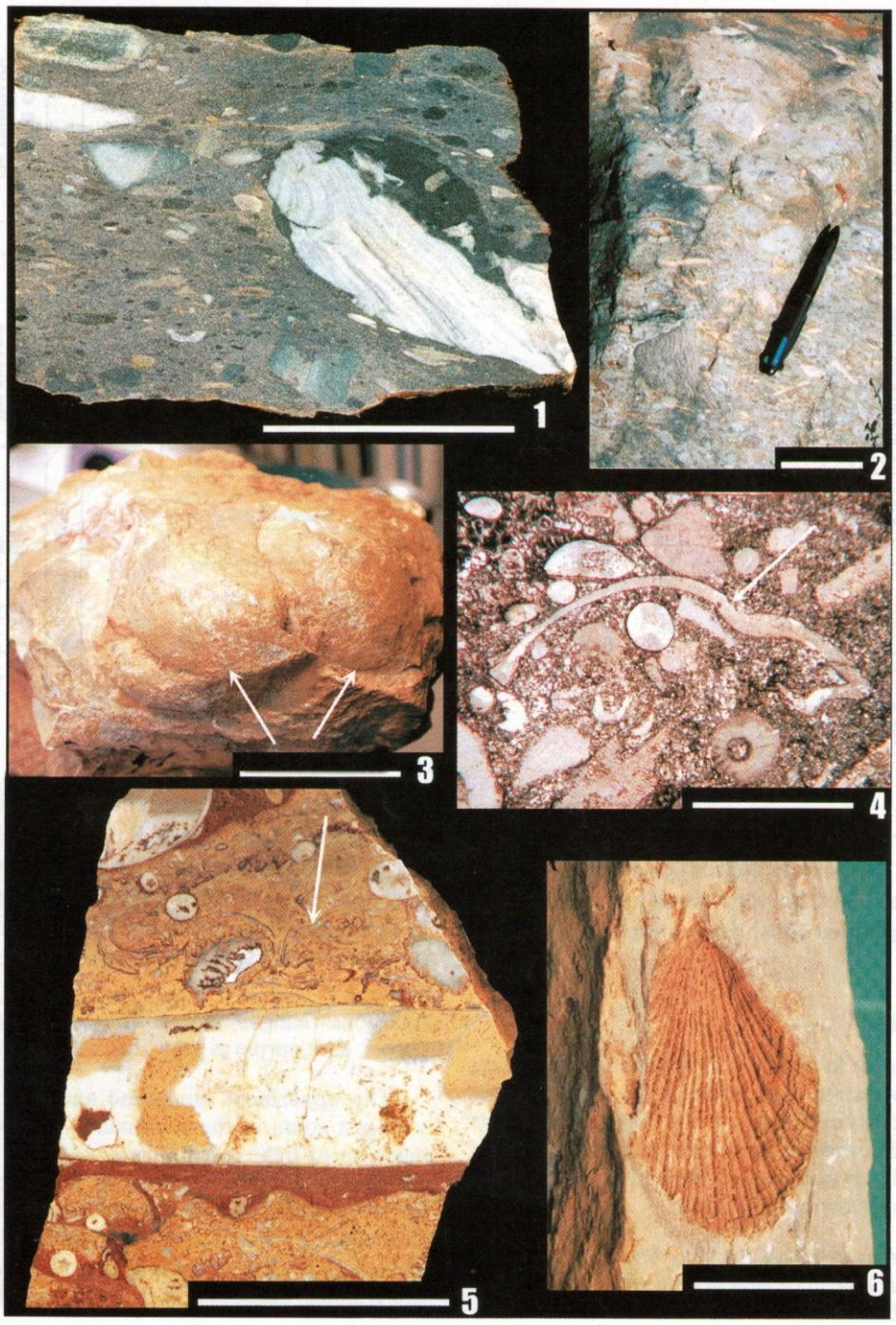

Plate 1: (1) Photograph of a polished slab cut off from a huge pebbly mudstone float derived from the lower part of the Tistung Formation collected from the upper branch of the Durlun Khola. Scale bar is 5 cm. (2) Photograph of weathered surface of a large pebbly mudstone float derived from the lower part of the Tistung Formation, picked up from the alluvium of the midstream of the Tungan Khola. Scale bar is 5 cm. (3) Photograph of Ordovician trilobites (arrows) collected from fossiliferous limestone of the basal part of the Godavari Formation in Phulchauki area. The detailed locality and horizon of the fossil are shown in Figs. 3 and 8, respectively. Scale bar is 5 cm. (4) Microphotograph of a thin section of fossiliferous limestone of the basal part of the Godavari Formation in Phulchauki area. An arrow shows a trilobite. Crossed polarized light. Scale bar is 2 mm. (5) Photograph of a polished slab of fossiliferous limestone obtained from the basal part of the Godavari Formation in Phulchauki area. An orthoceratid and trilobites (arrows) are shown. Scale bar is 5 cm. (6) Photograph of a brachiopod imprint on siltstone of the uppermost part of the Godavari Formation collected from the WNW slope of Phulchauki area. Scale bar is 1 cm.

about 1 cm in size, of shaly and silty rocks embedded in a Tistung-type green and purplish phyllitic matrix, bedding and sorting are not visible." Judging from the locality and the similarity of lithologic characters, the pebbly mudstone floats found from the study area are of the same kind as the "conglomerate boulders" reported by Arita et al. (1973), as well as the floats of "colored conglomerate" by Stöcklin and Bhattarai (1981). Because of the matrix-supported structure of the pebbly mudstones, the present author considers these rocks as the debris flow deposits. The present study elucidated that the horizon of the pebbly mudstone lies within the lower part of the Tistung Formation. On the other hand, there are no significant changes of the lithofacies nor hiatuses of deposition in the succession of the lower part of the Tistung Formation. The pebbly mudstone of the study area is equivalent to the conglomerate reported by Kumar et al. (1978) in containing well-elongated pebbles. The Tistung Formation has a fault contact with the injection complex composed of granites and gneisses exposed to the north of Kathmandu (Arita et al. 1973; Stöcklin and Bhattarai 1980), from where Kumar et al. (1978) reported a conglomerate bed. Judging from the geology of the Kathmandu area, the conglomerate reported by Kumar et al. (1978) can not be considered as the basal conglomerate of the Tistung Formation, but to an intraformational conglomerate bed within the Tistung Formation. Thus, the above evidences point to the conclusion that the conglomerates described by Arita et al. (1973), Stöcklin (1980) and Stöcklin and Bhattarai (1980, 1981), as well as by Kumar et al. (1978) are not the basal conglomerate of the Tistung Formation, but are debris flow deposits intercalated within the formation.

Kumar et al. (1978) reported an outcrop of the contact of the Tistung and the Markhu Formation along the Tistung-Kulikhani road. They concluded that the outcrop was an important piece of evidence of the angular unconformity between both formations. Despite the importance and indispensableness of the outcrop for the recognition of the angular unconformity, they offered no explanation of the stratigraphic and structural relationships of the rocks above and below at the outcrop. Stöcklin (1980) and Stöcklin and Bhattarai (1980, 1981) studied the stratigraphy, and sedimentary and geologic structures of the area west of the Bagmati River, and they reached to the conclusion that no basal conglomerate of the Tistung Formation was detected. They, on the other hand, clarified the gradational change of lithofacies from the Markhu Formation to the Tistung Formation. Furthermore, they did not recognize the stratigraphical and structural discontinuity between the two formations in the area where Kumar et al. (1978) reported the outcrop of "angular unconformity".

Therefore, based on the description regarding the relationship between the two formations presented by Stöcklin (1980) and Stöcklin and Bhattarai (1980, 1981), the outcrop reported by Kumar et al. (1978) is not an angular unconformity. The angularity of strata at the outcrop described by Kumar et al. (1978) probably is a post-depositional structural disruption such as a fault.

In order to know the stratigraphic relationship between the Markhu Formation of the Bhimphedi Group and the overlying Tistung Formation of the Phulchauki Group, I have investigated the catchment area of the Tungan Khola and the upstream area of the Durlun Khola (Fig. 3). In these areas the rock strata are poorly exposed, therefore the obtained columnar sections are all of disconnected ones as seen in Fig. 6.

The upper part of the Markhu Formation is made up of high-grade metamorphic equivalents of the alternation of siltstone and limestone of varied thicknesses and some thin intercalations of quartzose sandstone. Locally either siltstone or limestone is predominant. Whereas the Tistung Formation consists mostly of metasediments of siltstone but includes some thin interbeds of quartzose sandstone and argillaceous limestone. Thus the two formations are lithologically not so radically different but can only be distinguished by the abundant intercalations of limestone in the Markhu Formation. No coarse clastic rocks such as conglomerate have been found. The very boundary of the two formations is drawn at the horizon of the uppermost limestone bed of the Markhu Formation. This boundary runs rectilinearly in a nearly East-West direction parallel to the midstream valley of the Tungan Khola.

Both the Markhu and the Tistung formations run parallel to each other with a strike N70°W to East-West. The complete coincidence of the strikes and dips of the beds of the two formations and their boundary line implies that no structural discontinuity or angularity exists within the sequence from the Markhu to the Tistung Formation. In summary, the Bhimphedi and the Phulchauki groups are conformable and no structural discontinuity is recognized within the sequence.

Age of the Phulchauki Group

Stöcklin et al. (1977) reported an unnamed species of cystoids from the Chandragiri Formation in the Chandragiri area, and assigned the age of the fossil to middle Late Ordovician to Middle Silurian. Bordet et al. (1960) reported some trilobites and brachiopods from ferruginous concretions of the Chitlang Formation in Phulchauki area, and assigned the age of the Chitlang Formation to Silurian. O'Rourke (1961) included two figures of brachiopods and trilobites in his report yielded from the Chitlang Formation and the probable Chandragiri Formation from Phulchauki area, the same area from where Bordet et al. (1960) reported the marine invertebrate fauna, but did not give any palaeontological description and age. The trilobite fauna of Bordet et al. (1960) includes a genus Pterogometopus, which was assigned to Silurian age. Moore (1959) on the other hand assigned its age to Middle to Late Ordovician. As after Bordet et al. (1960), no further works were carried out on the fossils from the Phulchauki Group, the age of Chitlang Formation has been considered to be either Middle to Late Ordovician or Silurian in age.

During the present study, the author discovered trilobite fossils from the Godavari Formation (Fig. 3 and 9; Plate 1-3

to 1-5) (Suzuki and Funakawa, in prep.). The age of one of the trilobites *Illaenus* is assigned to Ordovician. This work confirms that the middle to upper parts of the Phulchauki Group (the Chandragiri, the Chitlang, and the Godavari Formation) is Ordovician.

Correlation between the Phulchauki Group and the proximal Tethys sediments distributed in the High Himalaya

On the basis of lithostratigraphy and newly obtained palaeontological data, the Phulchauki Group can be correlated to the proximal Tethys sediments distributed in two areas, the Annnapurna area (Bordet et al., 1971) and the north of Qomolangma (Everest) area (MG/MR, 1982). As shown in Fig. 9, the Chandragiri and the Chitlang formations are correlated with the Nilgiri and the North Face Quartzite formations in the former area and the Jiacun and the Alai formations in the latter area, respectively. The lower to middle parts and the upper part of the Godavari Formation are also comparable with the lower part and the middle part of the "formation sombres" in the former area, and the Goulongri and the Hodgshantou formations in the latter area, respectively.

Detachment system in Kathmandu Nappe

In the areas of Qomolangma and Annapurna of the High Himalaya, Ordovician Tethys sediments predominantly composed of limestone are separated from the top section of the Higher Himalayan Crystallines of probably Cambrian age by a detachment fault. The Kathmandu Nappe also, has a thick Ordovician sedimentary sequence dominated by limestone (the Chandragiri, the Chitlang and the Godavari formations) resting over the more arenaceous Tistung Formation. At Tikabhairav Village, in the south of Kathmandu (Fig. 2), however, a transitional change of lithofacies was recognized between the Tistung and the Chandragiri formations without any stratigraphic discontinuity. In spite of the careful field investigation in the study area, no distinct evidence of the presence of detachment fault has been found within the sequence of the Phulchauki Group. More detailed further study may require to confirm the presence of detachment faults in the Kathmandu Nappe.

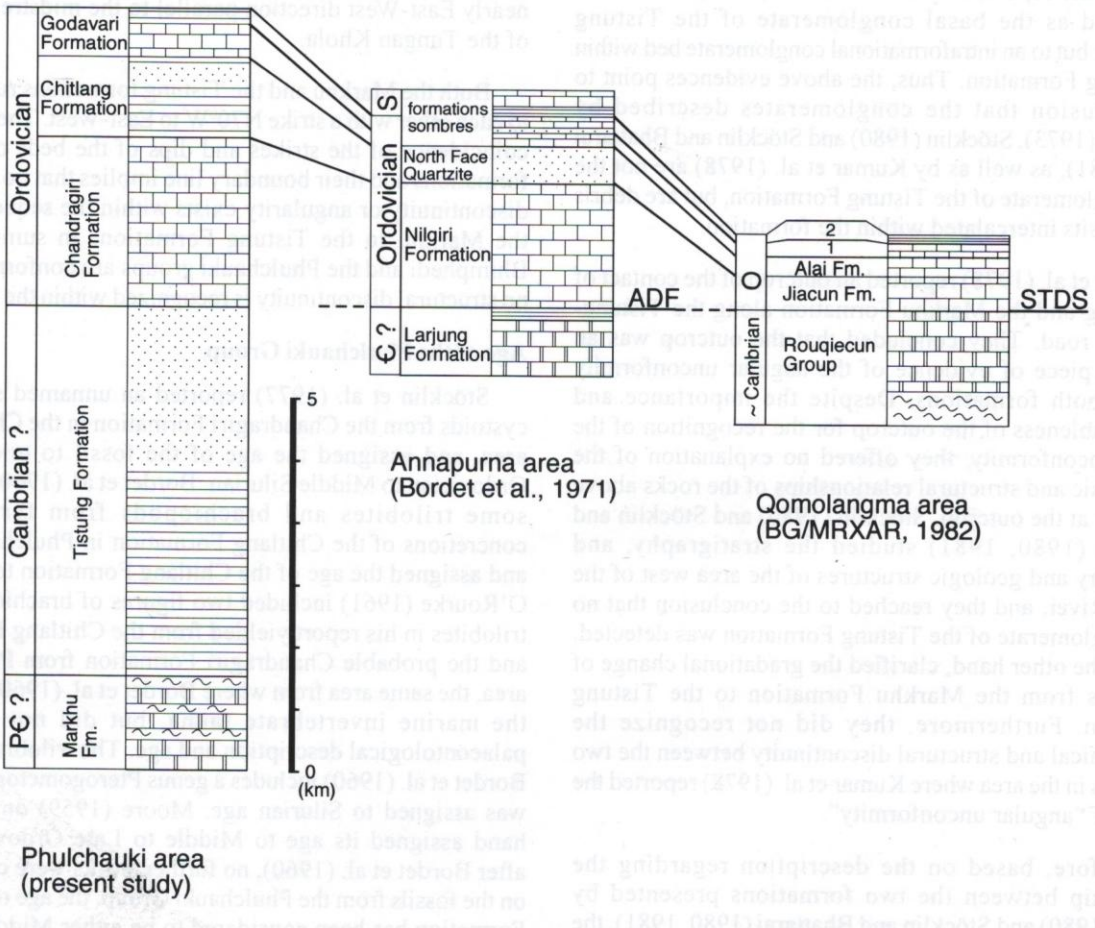

Fig. 9: Stratigraphic correlation between the Tethys sediments (Phulchauki Group) of the Lesser Himalayan Crystalline nappe and the proximal Tethys sediments of the Higher Himalaya. QD: Qomolangma Detachment (Burchfiel et al. 1992; Hodges et al. 1992); AD: Annapurna Detachment (Brown and Nazarchuk 1993); 1: Goulongri Formation; 2: Hongshantou Formation.

CONCLUSIONS

Based on the present study the following conclusions are made:

1. The Phulcahuki Group may be divided into only four formations as Sopyang Formation of Stöcklin (1980) and Stöcklin and Bhattarai (1980, 1981) does not qualify to be defined as a separate formation. All boundaries of lithostratigraphic units of the Phulchauki Group are conformable, and any kind of stratigraphic hiatus was not found throughout the whole sequence.

2. Pebbly mudstone of the Tistung Formation can not be taken as an evidence of stratigraphic breaks, as it is an intraformational debris flow deposit.

3. The Bhimphedi and the overlying Phulchauki groups are transitional in lithofacies, and no stratigraphic or structural discontinuity is found between them.

4. Preliminary identification of some newly collected trilobite fossils indicate that the Godavari Formation, the youngest formation of the Phulchauki Group, is of Ordovician age, and not of Silurian age as previously designated.

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REFERENCES

Arita, K., Ohta, Y., Akiba, C., and Maruo, Y., 1973, Kathmandu region. In: Hashimoto, S., Ohta, Y., and Akiba, C. (eds.), *Geology of the Nepal Himalayas*, Saikon Publishing Co. Ltd., Sapporo, pp. 99–145.

Bordet, P., Cavet, J., and Pillet, J., 1960, La faune silurienne de Phulchauki prÈs de Kathmandu (Himalaya du NÈpal). SociÈtÈ GÈologique de France, Bulletin, sÈr. 7, v. 2, pp. 3–14.

Bordet, P., Colchen, M., Krummenacher, D., Le Fort, P., Mouterde, R., and Remy, M., 1971, Recherches GÈologiques dans L'Himalaya du NÈpal, RÈgion de la Thakkhola. ...*ditions du Cnetre National de la Recherche Scientifique*, Paris, 275 p.

Brown, R. L. and Nazarchuk, J. H., 1993, Annapurna detachment fault in the Great Himalaya of central Nepal. In: Treloar, P. J. and Searle, M. P., (eds.), *Himalayan Tectonics*. Geological Society Special Publication, no. 74, pp. 461–473.

Burchfiel, B. C., Chen, Z., Hodges, K. V., Liu, Y., Royden, L. H., Deng, C., and Xue, J., 1992, The South Tibetan Detachment System, Himalayan orogen: Extension contemporaneous with and parallel to shortening in a collisional mountain belt. Geological Society of America Special Paper 269, 41 p.

Hagen, T., 1969, Report on the geological survey of Nepal, Volume 1, Preliminary reconnaissance: Z¸rich, Denkschriften der Schweizerischen Naturforschenden Gesselschaft, MÈmoires de la SociÈtÈ HelvÈtique des Sciences naturelles 86, 185 p.

Hodges, K. V., Parrish, R., Housh, T., Lux, D., Burchfiel, G. C., Royden, L., and Chen, Z., 1992, Simultaneous Miocene extension and shortening in the Himalaya orogen. Science, v. 258, pp. 1466–1470.

Kumar, R., Shah, A. N., and Bingham, D. K., 1978, Positive evidence of a Precambrian tectonic phase in central Nepal, Himalaya. Journal of the Geological Society of India, v. 19 (11), pp. 519–522.

Ministry of Geology and Mineral Resources, 1982, Regional Geology of Xizang (Tibet) Autonomous Region. *People's Republic of China, Ministry of Geology and Mineral Resources, Geological Memoirs*, ser. 1, no. 31, Geological Publishing House, Beijing, 707 p.

Moore, R. C., 1959, Treatise of Invertebrate Paleontology, Part O, Arthropoda 1. Geological Society of America, University of Kansas Press, 560 p.

O'Rourke, J. E., 1961, Paleozoic banded iron-formations. Economic Geology, v. 56, pp. 331–361.

O'Rourke, J. E., 1962, The stratigraphy of Himalayan iron ores. American Journal of Science, v. 260, pp. 294–302.

Shrestha, S. B., Maskey, N. D., Sharma, T., and Bashyal, R. P., 1993, Geology and mineral resources of Nepal. Atlas of mineral resources of the ESCAP region, Explanatory Brochure, v. 9, 107 p.

Stöcklin, J., 1980, Geology of Nepal and its regional frame. Journal of Geological Society London, v. 137, pp. 1–34.

Stöcklin, J. and Bhattarai, K. D., 1980, Geological map of Kathmandu area and central Mahabharat Range. United Nations Development Programme, Kathmandu, scale 1:250,000, 1 sheet.

Stöcklin, J. and Bhattarai, K. D., 1981, Geology of Kathmandu area and central Mahabharat Range, Nepal Himalaya. HMG/UNDP Mineral Exploration Project Report (unpublished), New York, 86 p.

Stöcklin, J., Termier, G. and Bhattarai, K., 1977, A propos des roches fossilifËres de Chandragiri (Mahabharat, Himalaya du NÈpal). SociÈtÈ GÈologique de France, Bulletin, v.19 (2), pp. 367–373.