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Note on the Tethyan Sedimentary Series of the Manaslu Region (Northern Nepal)

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2 Text-Figures and 2 Plates (in pocket)

Nepal
Tethys
Stratigraphy

Contents

Notizen zu den sedimentären Tethysserien des Manslu-Gebietes (Nord-Nepal)

Zusammenfassung

Es werden die Ergebnisse der geologischen Geländearbeit in den Tethysserien des oberen Shiar Khola und Burhi Gandaki vorgelegt. Diese Untersuchungen erfolgten im Rahmen eines deutschen Paläomagnetik-Projekts, das von E. APPEL (Universität Tübingen) organisiert wird.

Die stratigraphische Entwicklung entspricht der des Gebietes Thakkola-Manang, außer im Zeitabschnitt Oberpaläozoikum–Skyth. Die unterkarbone Tilicho-Lake-Formation scheint wie im von COLCHEN et al. (1986, S. 85) bearbeiteten Nar-Gebiet zu fehlen. Die Thini-Chu-Formation (Perm) erreicht die außergewöhnliche Mächtigkeit von wenigstens 1500 m und besteht überwiegend aus tonig-siltigen Gesteinen. Im obersten Teil der Formation wurde eine etwa 200 m mächtige Wechselfolge von Karbonaten und Peliten entdeckt. Die Karbonate zeigen Flachwasserfazies. Es gibt Anzeichen, daß die Absenkung, welche zur Bildung der kondensierten Sedimente der Taba-Kurkur-Formation (Skyth–Anis) geführt hat, örtlich bereits im obersten Perm eingesetzt hat. Faziesunterschiede im Jungpaläozoikum der Tibetischen Zone werden als Folge der Riftingprozesse am Nordrand Indiens erklärt. Damit hängt auch das Aufdringen basaltischer Vulkanite (Panjal) zusammen.

Die Tamba-Kurkur-Formation ist bis auf wenige Meter reduziert oder fehlt überhaupt. Wir vermuten, daß submarine Strömungen zu Erosion bzw. Nicht-Sedimentation geführt haben.

Tektonik: Die Tethysserien zeigen Faltenbau mit wechselnder Vergenz wie in den meisten Gebieten der Tibet-Zone. Weiters findet man lokale Scherflächen in Zusammenhang mit Schuppenstrukturen oder Vertikalbrüchen.

Abstract

The results of geological field work in the Tethyan sedimentary sequences of the upper Shiar Khola and Burhi Gandaki are presented. They accompanied the German palaeomagnetic project organised by E. APPEL (University of Tübingen).

The stratigraphic development resembles that of the Thakkhola-Manang region except in the Upper Palaeozoic–Scythian. The Lower Carboniferous Tilicho Lake Formation seems to be missing like in the Nar area (COLCHEN et al., 1986, p. 85). The Thini Chu Formation (Permo-Carboniferous) reaches the abnormal thickness of at least 1500 m and shows predominance of argillaceous and silty rocks. In the uppermost part of the formation a carbonate-pelite alternation of about 200 m thickness was found. The carbonates are of shallow-water type, and there are indications that the subsidence, which led to the condensed sediments of the Tamba Kurkur Formation, started locally already in the uppermost Permian. Facies diversification in the Upper Palaeozoic of the Tibetan Zone is explained by the process of rifting along the northern margin of India. The basaltic volcanics (Panjal) are related to the rifting.

The Tamba Kurkur Formation is reduced to a few metres or is even missing. We explain this phenomenon as caused by submarine erosion by currents respectively non-deposition.

Tectonics: The Tethyan succession shows fold structures of varying vergence like in most parts of the Tibetan Zone. Additionally local shear planes in connection with schuppen structures and normal faulting are observed.

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1. Preface

As part of the palaeomagnetic project on the Himalayas organized by E. APPEL (University of Tübingen, Germany) the Shiar Khola and Upper Burhi Gandaki regions were investigated. This expedition with cooperation with the Tribhuvan University took place in autumn 1996. We attended to do the geological work accompanying the palaeomagnetic sampling. Due to this target we did not have the opportunity for detailed stratigraphic studies and systematic palaeontological sampling.

The pioneer work done by COLCHEN et al. (1986) gives general geological information on the area. For palaeomagnetic sampling, however, more details are required regarding the geological position of the sites. Further we found several deviations from the French map 1 : 200 000. We are presenting maps in the scale 1 : 63 350 of the areas built up of the Tethyan sedimentary series (Text-Fig. 1; Pls. 1, 2). Certain formations show facies changes as compared to the Manang, Thakkhola and Dolpo regions to the west. This note deals with the peculiarities of the Burhi Gandaki area. It should not be understood as a complete description of the region.

2. The Shiar Khola Area

(Plate 1)

We are going to give a description of the section along the Shiar Khola, a tributary of the Burhi Gandaki. At Chhokang village a band of leucogranite crosses the valley. The granite intruded the calc-silicate gneisses and marbles of the upper Central Crystalline (not in map). Towards Rachhengompa the metamorphic grade decreases and the metacarbonates pass into several thousand metres thick Nilgiri Limestone. These thick-bedded, bluish grey, impure limestones correspond to Dhaulagiri Limestone and Garbyang Formation. The Nilgiri Limestone is dated Ordovician (see COLCHEN et al., 1986).

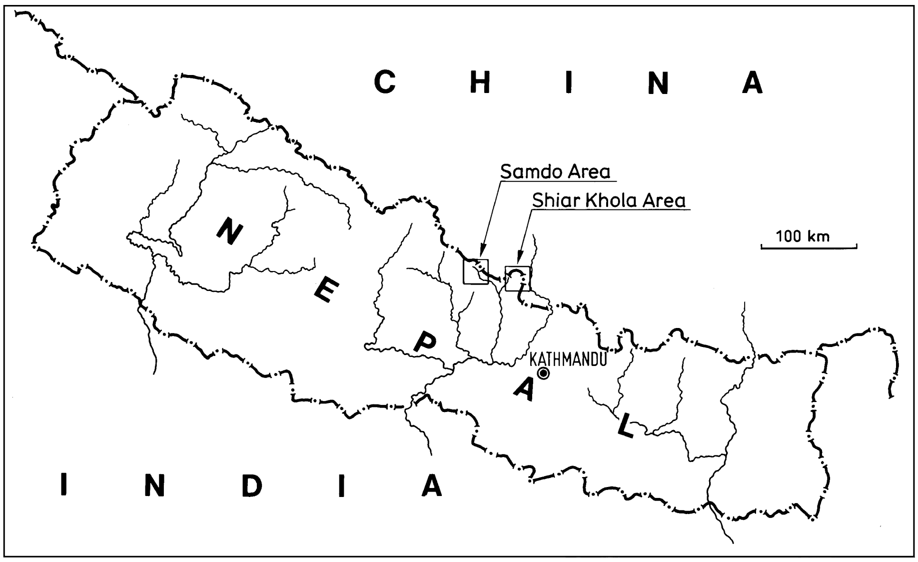
North of Chule arenaceous influx increases and we find an alternation of the bluish limestones with fine-grained quartzites. This sequence, 300 to 400 m thick, corresponds to the North Face Quartzite of the Annapurna-Dhaulagiri area. In the French map Silurian (Dark Band Formation) is shown there, north of Nile. Apparently the talus of the black slates falling down from the overlying Dark Band Formation was mistaken as outcrop. In fact the latter formation is only about 200 m thick and starts further north. It consists of finely laminated, black slates. On the basis of graptolites found in the Thakkhola area (EGELER et al., 1964; BORDET et al., 1971) the Dark Band Formation is accepted as Silurian, the uppermost dark carbonates as Lower Devonian. The last named member, however, was not observed in the Shiar Khola.

At the top the black slates pass into the grey to green, parallel laminated slates, siltstones and fine-grained sandstones of the Tilicho Pass Formation (Devonian). In the lower portion of this formation a few metres thick band of grey carbonate is interbedded. In this type of carbonates Upper Devonian fossils were found in the region further to the west (FUCHS & MOSTLER, 1969; FUCHS et al., 1988).

According to the map by COLCHEN et al. (1986) the Lower Carboniferous Tilicho Lake Formation crosses the Shiar Khola at Maigompa (Mu). We found grey to black, thin-bedded slates there, but no carbonates and the other lithologies characteristic of the Tilicho Lake Formation. Since we did not observe this formation neither in the Shiar Khola nor in the Larkya-Samdo area, we suspect a gap between the Tilicho Pass Formation and the Thini Chu Formation like in Dolpo (FUCHS, 1967, 1977). This view is supported by the French authors themselves, who record that in Nar Valley, an area just to the west from the Burhi Gandaki region, the Chulu Formation (Thini Chu Formation) rests directly on Lower Devonian beds (COLCHEN et al., 1986, p. 85). In many other Himalayan regions, also a lacuna is found below the Permian (eg. Garhwal [HEIM & GANSSER, 1939]). From the lithology of the dark slates of Maigompa, we think that they belong already to the Thini Chu Formation.

Unfortunately the paper by GARZANTI et al. (1994) came into our hands when our manuskript was already in press. GARZANTI et al. present a detailed stratigraphic study of the Late Paleozoic rock series. They give the Thini Chu group status and discern a series of formations and subunits. However, we are afraid that in the course of geological mapping these units would be difficult to trace in the field. Anyhow, we shall use the term “Thini Chu Group” in future publications, which as documented by GARZANTI et al. is in its major part carboniferous.

From Maigompa to Changyam-Yarjung Khola junction, the Shiar Khola is built by the rocks of the Thini Chu Formation. Even if we accept internal folding, a primary thickness of at least 1500 m must be assigned. This is a surprising amount, but fits well with the tendency of increasing thickness towards the east. The Thini Chu Formation is 30–70 m in western Nepal, 100–120 m in central Dolpo, 180–300 m in eastern Dolpo (FUCHS, 1977), 470 m in the Kali Gandaki (EGELER et al., 1964) and still increases in thickness towards the east (BORDET et al., 1971, 1975).



Text-Fig. 1.
Location of the mapped areas.

Also the composition of the Thini Chu Formation is abnormal in the Shiar Khola. Dark, grey and greenish, silty slates and siltstones build up the bulk of the formation, whereas arenites form only sporadic intercalations. This complex probably corresponds with the Marsyandi Formation and Col Noir Shales (GARZANTI et al., 1994). In contrast quartzites, sandstones and conglomerates are much more frequent and occur approximately in equal volume with the silty argillites in the regions to the west. In the upper half of the formation there are lenticular bodies of green and red, amygdaloidal basalt flows and tuffaceous shales intercalated in the silty slates. Their thickness may be several tens of metres. Also tillitic sandstones are associated. These rocks were already reported by the French (COLCHEN et al., 1986, p. 85) and are dealt in detail by GARZANTI et al. (1994).

A discovery is the importance of carbonates in the uppermost 200 m of the Thini Chu Formation. Mostly they are grey, brownish weathering carbonate-sandstones to coarse-grained impure limestones rich in fossils: crinoids, brachiopods, bivalves, bryozoas and solitary corals. The thick-bedded carbonates alternate with dark silty slates (Kuling facies). Less common are dark limestone beds. Light grey to brownish, fine-grained to dense limestones in the uppermost Thini Chu Formation are lithologically similar to the Tamba Kurkur Formation, from which they can be distinguished only by the occurrence of Permian brachiopods and crinoids. These limestones seem to correlate with the topmost biocalcarenites (TBC) of GARZANTI et al. (1994). In one locality – NNE from the Changyam/Yarjung Khola junction – a 6 m block of massive, white limestone was observed. Obviously it represents a patch reef.

Thus the Permo-Carboniferous of the Shiar Khola area shows interesting peculiarities of facies. The predominance of silty argillites and rare occurrence of arenites suggests basin conditions and distance from the coast for the major part of the Thini Chu Formation. The carbonates in the youngest portion of the formation indicate a phase of shallowing before the subsidence marked by the condensed sediments of the Scythian.

The variety of facies in the Permian appears to be related to the process of rifting. The newly formed northern margin of the Indian Continent was not a straight line and further a series of intra-continental fractures and grabens came into being close to the continent's northern edge (FUCHS & LINNER, 1996). Faulting provided ways for the extrusion of the Panjal Volcanics. Individual block movements, tilting etc. are responsible for the different range of the pre-Permian gaps (FUCHS, 1982).

The Tamba Kurkur Formation is a marker horizon which makes it easy to recognize the base of the Triassic in most Tethyan regions of the Himalaya. This is not so in the Shiar Khola. The uppermost beds of the Permian carbonates are sometimes lithologically similar to the limestones of the Tamba Kurkur Formation. Distinction is possible only on the basis of fossils: crinoids and brachiopods in the Permian, ammonites in the Scythian. In the ravine NE from the Changyam/Yarjung Khola junction the Permian/Triassic boundary is excellently exposed. The top of the Thini Chu Formation is composed of 3 m of black slates with crinoids and pelecypods and a dm-layer of grey quartzite. In the uppermost 0.5 m the black slates become more and more calcareous. At the top a black crinoid limestone (0–4 cm) exhibits lenticular form, because on a wavy plane of erosion the light grey to brownish, dense limestones of the Tamba Kurkur Formation fill pockets in the underlying rocks. Thus a phase of erosion or non-deposition is indicated there. The Tamba Kurkur Formation is only 5 m thick in that section. It is not possible to follow the Tamba Kurkur Formation along the strike. To the west the Permian is in direct contact with the Mukut Limestone. There the contact is probably tectonic. Still further west, in the upper course of the Changyam valley, again the Mukut Limestone succeeds immediately the Permian (south of point 13501). To the west from there we observed the Tamba Kurkur Formation again, but reduced to a few metres. The formation consists of the typical light to medium grey, dense limestones with nodular s-planes. Also there the lithology of the uppermost Permian carbonates ressembles the Scythian, only fossils allow distinction.

Still further to the west the Tamba Kurkur Formation is reduced to 0.75 m of nodular, grey limestone with ill-preserved ammonites.

Locally the Tamba Kurkur Formation may be tectonically squeezed, but we think that it is already primarily reduced in the Shiar Khola region. Further it is interesting that the coarse-grained Permian limestones full of fossil detritus may be found immediately under the Scythian limestones, whereas in other sections grey dense limestones resembling the Scythian are observed below the Tamba Kurkur Formation. Sporadic coarse crinoid stems and brachiopods document that these limestones are still Permian. We are inclined to explain these facts in the following way. The subsidence causing the change from shallow water to bathyal condensed sediments was not synchronous. Generally the change marks the Permian/Triassic boundary; locally the condensed sedimentation may have started already in the uppermost Permian. In one locality in Dolpo FUCHS (1967, p. 169, 173) found a Permian fauna at the base, the first ammonites in the top of the basal limestone bed of the Tamba Kurkur Formation. In the Shiar Khola the lithological change occurred in the uppermost Permian and not with the Permian/Triassic boundary.

Observed planes of erosion or non-deposition are regarded as subaqueous phenomena. Possibly the missing of the Tamba Kurkur Formation goes back to submarine erosion or non-deposition. However, to clarify these questions detailed stratigraphic-palaeontological studies would be necessary. In the Manang area NICORA & GARZANTI (1997) did such detailed studies and came to the conclusion that the condensation, reworking and ravinement processes at the Permian/Triassic boundary are

> *" ... explained as due to starvation and subaqueous redeposition or even erosion of underlying beds during a major stepwise transgression ... " (p. 50).*

These authors do not favour subaerial erosion.

The Mukut Limestone (Anisian–Lower Norian) shows the normal development: a thin-bedded alternation of dark limestone and marly shale. Ammonites of Ceratites type are frequent in the lowest portion of the formation. As a mapable unit the Mukut Limestone can be easily identified throughout northern Nepal. Stratigraphic subdivisions done in certain sections (KRYSTYN, 1982) are of local importance and can not be followed over large distances. Due to strong internal folding the thickness of the Mukut Limestone can be given only roughly 200–400 m.

The Tarap Shales (Norian) are composed of grey to greenish silty shales and shaly siltstones of approximately 400–600 m thickness.

The Quartzite Series is not very pronounced. Blocks are found in the float and moraines, but in several sections the Kioto Limestone (Rhaetic–Lower Dogger) succeeds immediately the Tarap Shales. The lithology corresponds to the other regions of the Tibetan Zone: a thick-bedded alternation of blue to light grey limestones and dolomites with very subordinate shaly layers. The thickness is estimated to be 300–500 m.

At the top the Kioto Limestone passes into the Lumachelle Formation, a thin-bedded alternation of dark limestones, micaceous sandstones, ochreous weathering calcareous sandstones and pelites. In the synclines north of the Yarjung Khola the Upper Dogger formation is several hundred metres thick.

The Permian–Mesozoic succession shows south-directed folding. The fold structures are locally cut by shear and schuppen planes. These disturbances seem to have been directed from west towards east, across the strike.

Normal faults following the strike complicate the fold structures in the Kioto Limestone. This goes back to the discrepancy in competence between the Tarap Shales and the Kioto Limestone, and is a common phenomenon in the Tethyan Zone.

3. The Samdo Area

(Plate 2)

The lower course of the Shiar Khola and from the Shiar Khola-Burhi Gandaki confluence up the latter river we are in the Central Crystalline. In the area of Samagaon the calc-silicate gneisses and metacarbonates of the Central Crystalline pass into the slightly metamorphosed Nilgiri Limestone. This formation builds up the Sonam-Ghumnaja Himal. From Samagaon to Samdo steeply folded Nilgiri Limestone is found along the flanks of the valley. According to Colchen et al. (1986) the higher portions of the named massif (in their map Shathor-Lekhor) are built up of Silurian to Lower Carboniferous formations. It is certainly difficult to interpret the ice- and snow-clad flanks by means of binocular, but we think that the syncline in the peaks of the massif is composed of the Ordovician North Face Quartzite and not of younger formations. The north face of the Sonam Himal is built up by the North Face Quartzite, which forms the core of a huge anticline overturned towards the north. At the front of this almost vertical mountain face of 2600 m height we find the Dark Band Formation (Silurian) of the inverted limb. From there until the Lajing La in the north the whole Palaeozoic–Mesozoic succession is overturned.

The Tilicho Pass Formation (Devonian) is mostly hidden at Samdo, but well exposed in several hundred metres thickness in the mountains to the east. The map by Colchen et al. (1986) shows a band of the Lower Carboniferous Tilicho Lake Formation at Samdo village. Actually there are only outcrops of silty slates and arenites of the Thini Chu Formation. West of Samdo, in the Larkya Khola, there are only moraines at the localities where the French geologists show Tilicho Lake Formation in their map. Thus we think that like in the Shiar Khola area the Lower Carboniferous Formation is missing.

The Thini Chu Formation is very thick like in the Shiar Khola, but quartzites are much more frequent here. The mountains north of Samdo are built up of the Thini Chu Formation composed of dark, silty slates, siltstones, quartzites, and metabasalts (Panjal). Carbonites are very subordinate here.

NNW of Samdo, for instance, two bodies of basic volcanics cross the valley. Their thickness is approximately 150 m each and they are separated by 5 m thick grey quartzite. The vesicles of the volcanics are mainly filled with quartz and sometimes zeolite minerals. The basaltic rocks show greenschist metamorphic grade.

The Permian is followed by the Mukut Limestone. The Tamba Kurkur Formation was not observed in the area north of Samdo. Apparently it is missing like in some localities of the Shiar Khola. The thickness of the Mukut Limestone is approximately 200–250 m. The Tarap Shales are 300–700 m thick. The Quartzite Series about 100 m and Kioto Limestone (400–600 m) follow showing their normal lithological development.

The youngest formations, the Lumachelle Formation (150–200 m, Upper Dogger) and the Spiti Shales (Upper Jurassic–Lower Neocomian) are found in the core of the Lajing La Syncline. From the Sonam Himal north face up to the Lajing Pass all the succession is inverted. The overturned sequence represents the limb of the large north-directed antiform of the Sonam Himal. Similar large anticlines are reported from the north faces of the Annapurna, Nilgiri, Dhaulagiri and Kanjiroba Himals (Bordet et al., 1971; Fuchs, 1967, 1977).

North of Lajing La the mountains are built up of folded Kioto Limestone. The Lumachelle Formation seems to occur in two small synclines on the crest of the range forming the border to Tibet. All the folds are mainly directed towards the north. The slopes southeast of Gyala La are mostly covered by moraine material. Below the latter we expect Tarap Shales, which form the cores of the Kioto Limestone anticline mentioned above. Further west, in the slopes west of Gyala La, Mukut Limestone is exposed in the core of an anticline, which plunges axially towards the east under Tarap Shales. The limestones are intricately folded. The structures seem to be south-vergent. Due to these tectonics the Tarap Shales frequently exhibit pencil lineations. The pencils measuring up to 80 cm plunge with 200 towards 1150 (ESE).

Concerning the map by Colchen et al. (1986) corrections must be made. The anticline south of Gyala La exposes Mukut Limestone, but not the Thini Chu Formation.

The map by Colchen et al. (1986) shows a discrepancy between the region north of Samdo and the northern Shiar Khola. In the first the Kioto Limestone is rather thin, whereas the Lumachelle Formation is very thick. In the upper Shiar Khola it is the opposite. Actually almost all the area shown as Lumachelle Formation in the region north of Samdo is composed of Kioto Limestone (see Pl. 2), which fits well with the geology of the Shiar Khola.

West of Samdo, in the Larkya region, leucogranite of the Manaslu intrusion becomes prominent and replaces the sedimentary formations, which is already shown in the map by Colchen et al. (1986).

4. Conclusions

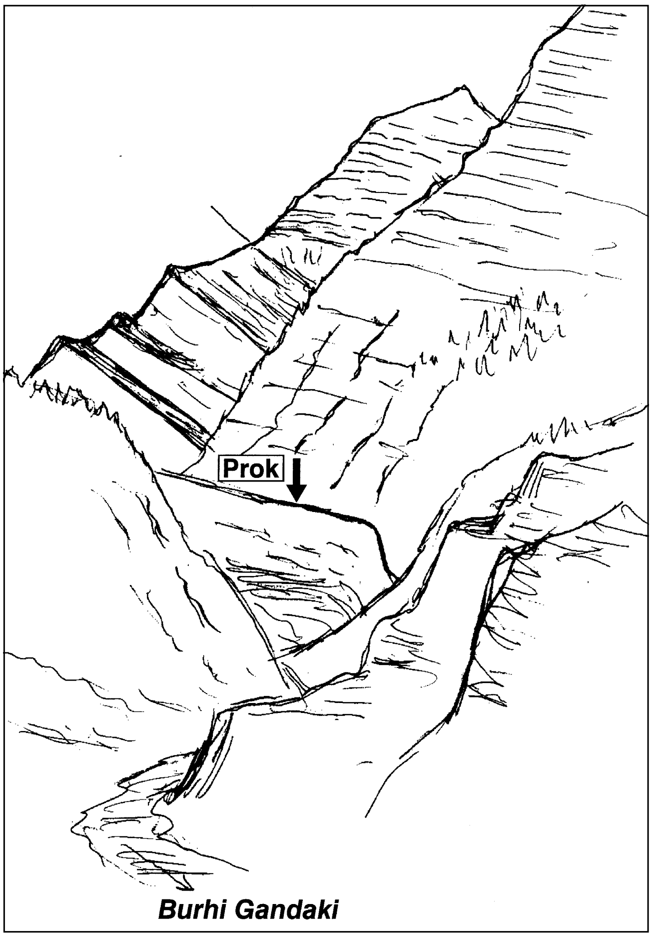
The Tethyan Zone of the upper Burhi Gandaki and Shiar Khola corresponds well with the Manang and Dolpo regions, but shows some distinct individual features.

Generally the metamorphism of the Central Crystalline passes away in the Tethyan sedimentary succession. Therefore there is no sharp boundary and both are regarded as one major structural unit (Fuchs, 1967; Bordet et al., 1971, 1975: Tibetan Slab; Colchen et al., 1986: High Himalayan Slab). Burg (1983), Burchfiel & Royden

(1985), COPELAND et al. (1987) and others stressed the importance of gravitational detachment tectonics between the crystallines and sedimentary series. Shear zones are reported from many places, but there are also many instances where the primary connection of crystallines and sediments is still preserved.

The conspicuous discordance in the mountains north of the village Prok in the Burhi Gandaki Valley may be caused by gravitational slump (Text-Fig. 2). There the metamorphic carbonates dip at an angle of approximately 450 N, whereas the succeeding series, probably Nilgiri Limestone, show dip of only 200 N (binocular observation). In the Shiar Khola and around Samagaon we did not observe shear zones. However, the huge north-directed fold observed from Sonam Himal to Annapurna, Dhaulagiri, and Kanjiroba Himals in the west are probably related with the Miocene uplift of the axial region and gravitional slump of the sedimentaries. These collapse tectonics occurred in a harmonic fold style and not along a distinct shear zone.

The stratigraphic succession of the Tibetan Zone commences with thick, monotonous, rhythmically bedded series deposited along a continental margin. In Nepal and westwards to Kumaun these series are composed of carbonates with cyclic silty to arenaceous impurities (Nilgiri-, Dhaulagiri Limestone, Garbyang Series). In the western Himalaya, Martolis and Haimanta are corresponding formations of non-calcareous flysch type. The continental slope sedimentation lasted from Late Precambrian to Ordovician.



Text-Fig. 2.
The discordance north of the village Prok, seen from the east.
Description in the text.

In the Silurian the Dark Band Formation indicates deep water graptolite shale facies in Burhi Gandaki, Thakkhola and eastern Dolpo (EGELER et al., 1964; BORDET et al., 1971; FUCHS, 1967). Westwards the basin facies is substituted by varicoloured shallow-water shales and limestones (HEIM & GANSSER, 1939; FUCHS, 1977).

In the Devonian the facies diversification still persists. The silty slates-sandstone alternation of the Tilicho Pass Formation indicates basin conditions in the east (Burhi Gandaki to eastern Dolpo). Towards the west limestone intercalations increase and we find transition to shallow-water dolomites and quartzites in western Dolpo (Muth Facies, FUCHS, 1967, 1977).

The Lower Carboniferous from western Dolpo to Manang is represented by the Tilicho Lake Formation composed of dark carbonates and pelites. In western Dolpo this formation is missing, probably due to pre-Permian and Permian erosion. A gap is also found in Kumaun (HEIM & GANSSER, 1939) and Spiti (HAYDEN, 1904; FUCHS, 1982). As we did not observe the Tilicho Lake Formation in the localities shown in the map by COLCHEN et al. (1986), we think that it is also missing in the Burhi Gandaki-Shiar Khola region.

The Permo-Carboniferous is represented by the Thini Chu Formation, a shallow water alternation of quartzites, sandstones, conglomerates, and pelites. BORDET et al. (1971) found fossils indicating Visean to Upper Carboniferous age in the lower part of the Thini Chu Formation of the Thakkhola. GARZANTI et al. (1994) show that also east thereof the Thini Chu Group comprises the Visean to uppermost Permian. The major part of the complex is carboniferous (Visean-Bashkirian).

In the Burhi Gandaki-Shiar Khola area the Thini Chu Formation exhibits very thick and predominantly argillaceous-silty development. From Dolpo in the west to Manang in the east, increase in thickness of the Thini Chu Formation was observed earlier (BORDET et al., 1971, 1975; FUCHS, 1967, 1977). Differences in coarse-clastics/pelite ratio and thickness seem to be caused by rifting. This process led to opening of grabens and smaller basins. Therefore we find coarse clastics along the basin margins and silty-argillaceous predominance in distal parts. Individual block movements are responsible for differences in the range of the pre-Permian gaps. Rifting also explains the occurrence of basic volcanics in Burhi Gandaki and Manang areas (BORDETet al., 1975; COLCHEN et al., 1986; GARZANTI et al., 1994). The volcanics correspond with the Panjal Volcanics of the NW-Himalaya. The occurrence of tillites suggests correlation to the Gondwanas of the Subcontinent, the Lesser Himalayas (Damudas) and Kashmir. In the same direction points the found of coal in the Thakkhola (BORDET et al., 1971).

An outstanding feature of the Burhi Gandaki-Shiar Khola region are the carbonates in the upper part of the Permian. Abundant fossil detritus indicates shallow-water conditions. Occasionally we find the lithology of the condensed sediments of the Tamba Kurkur Formation already in the uppermost Permian. This observation suggests that the subsidence to bathyal condition, which generally occurred at the Permian/Triassic boundary, in some places started already earlier. NICORA & GARZANTI (1997, p. 50) explain this transgression at the end of the Permian by accepting rapid thermal subsidence.

The Scythian to Anisian Tamba Kurkur Formation is very much reduced or even missing in the Burhi Gandaki region. Thus this marker horizon is insignificant there, a formation, which otherwise shows rather constant character throughout the Himalaya. The lithology indicates condensed sedimentation, as typical for the Tamba Kurkur Formation. Therefore we think that submarine relief and currents were responsible for the local non-deposition or erosion of the Tamba Kurkur Formation.

The rest of the Triassic shows normal development: the Anisian to Norian Mukut Limestone and Norian Tarap Shales. The Rhaetian Quartzite Series were observed in some sections, in others they are missing. This is due to tectonic complication or may be primary. The arenaceous influx was probably bound to fans and was not uniform all over the shelf. In Zanskar FUCHS & LINNER (1995) observed that the Quartzite Series are missing in the northern, distal parts of the shelf.

The Rhaetian to Lower Dogger Kioto Limestone is typically developed. It has been already emphasized that the Kioto Limestone has the normal thickness of approximately 500 m also in the region north of Samdo, where the map by COLCHEN et al. (1986) shows Lumachelle Formation instead of most of the Kioto Limestone.

The Upper Dogger Lumachelle Formation exhibits the typical shallow-water alternation of pelites, carbonates, and sandstones, but it is not so fossiliferous as in the type areas, Thakkhola and Dolpo.

The youngest formation, the Upper Jurassic to Lower Neocomian Spiti Shales, consists of black shales with impure sandy and calcareous layers. We observed the Spiti Shales only in the Lajing La Syncline of Samdo region.

Tectonics: Whereas the Central Crystalline and the transition zone to the Tethyan sediments shows uniform northern dip at medium angles, steep folding starts with the thick basal carbonate complex (Nilgiri Limestone). Huge anticlinal folds, overturned towards the north, were observed from Sonam Himal (SE of Samdo) Annapurna, Nilgiri, Dhaulagiri and Kanjiroba Ranges. The core of these folds is composed of Nilgiri (Dhaulagiri Limestone), but involves also the Palaeozoic–Mesozoic succession. Thus the southern parts of the Tibetan Zone often show northern vergence. The folds of the Shiar Khola region are throughout directed towards the south. Variation in vergence is frequently observed in the folds of the Tibetan Zone, even in one section. This is explained by the fact that the Tibetan Zone is only exceptionally overriden by higher thrust masses (eg Spongtang, Jungba-Amlung La in SW-Tibet). Thus the folds were not forced to escape in one direction only.

Generally folding is the predominant tectonic style of the Tibetan Zone. Imbrication occurred particularly where rigid formations are in contact with soft, mobile series. Axial plane cleavage is a common phenomenon.

In the Shiar Khola region shear planes accross the regional strike are observed. Movements occurred from west towards east. These structures, which dissect the folds, are caused by later compression along the strike.

Steep normal faults parallel to the strike are not rare in and close to Kioto Limestone; displacement against the Tarap Shales or the overlying Lumachelle Formation are observed.

North of Samdo a NNE–SSW-striking normal fault displaces the Thini Chu Formation against Mukut Limestone.

Finally we may say that the tectonics observed in the Tethyan Series of the Shiar Khola-Burhi Gandaki area fit well with the rest of the Tibetan Zone.

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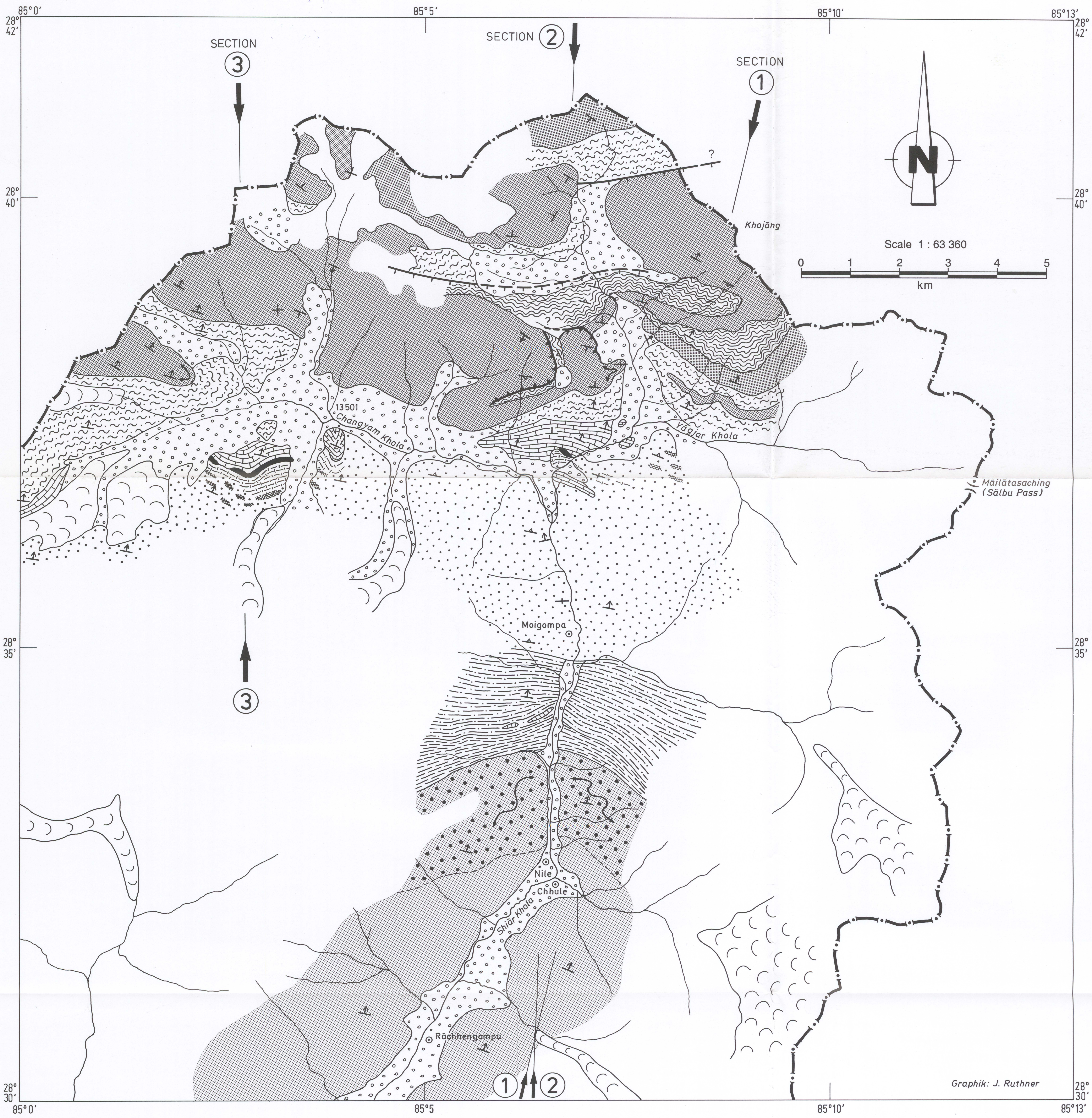
am 25. Mai 1997

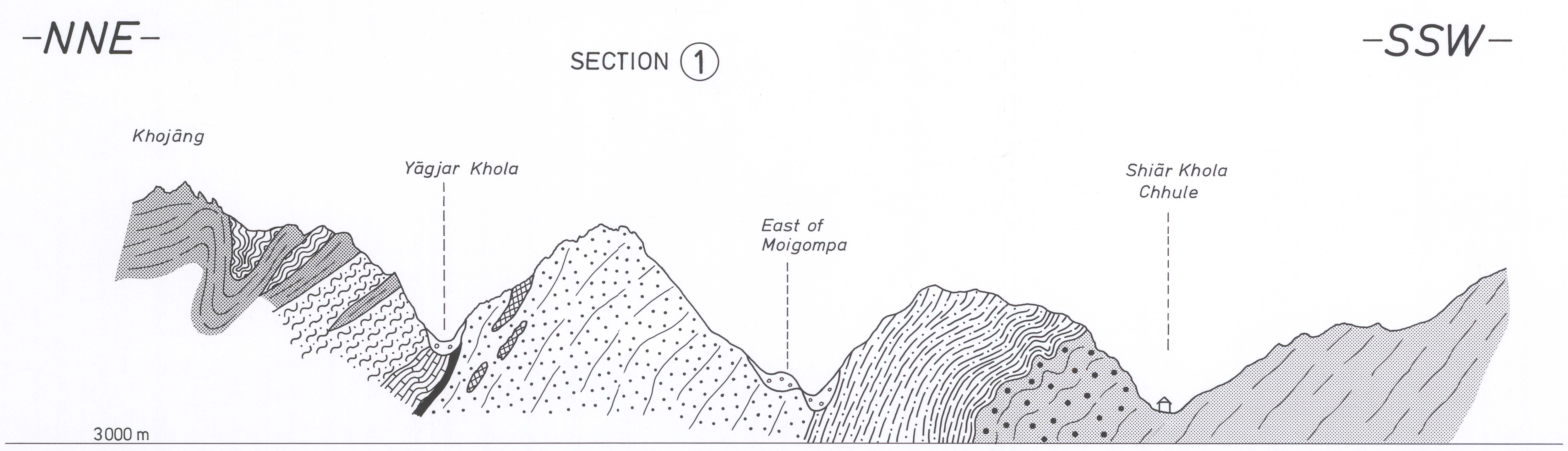
Jb. Geol. B.-A., **141**, H. 1, 1998 – Beilage 1
FUCHS, G. & PAUDEL, L.P. – Plate 1

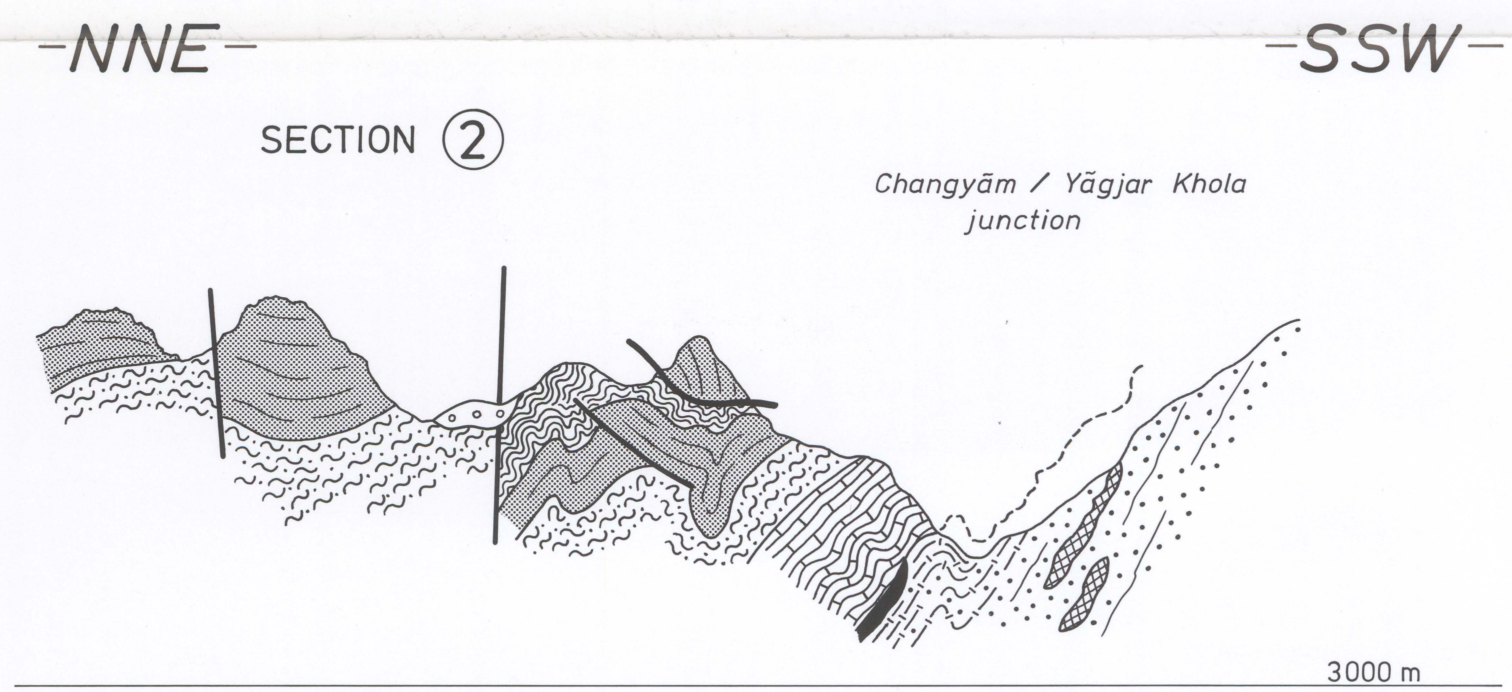
Geological Map of the upper Shiow Khola area

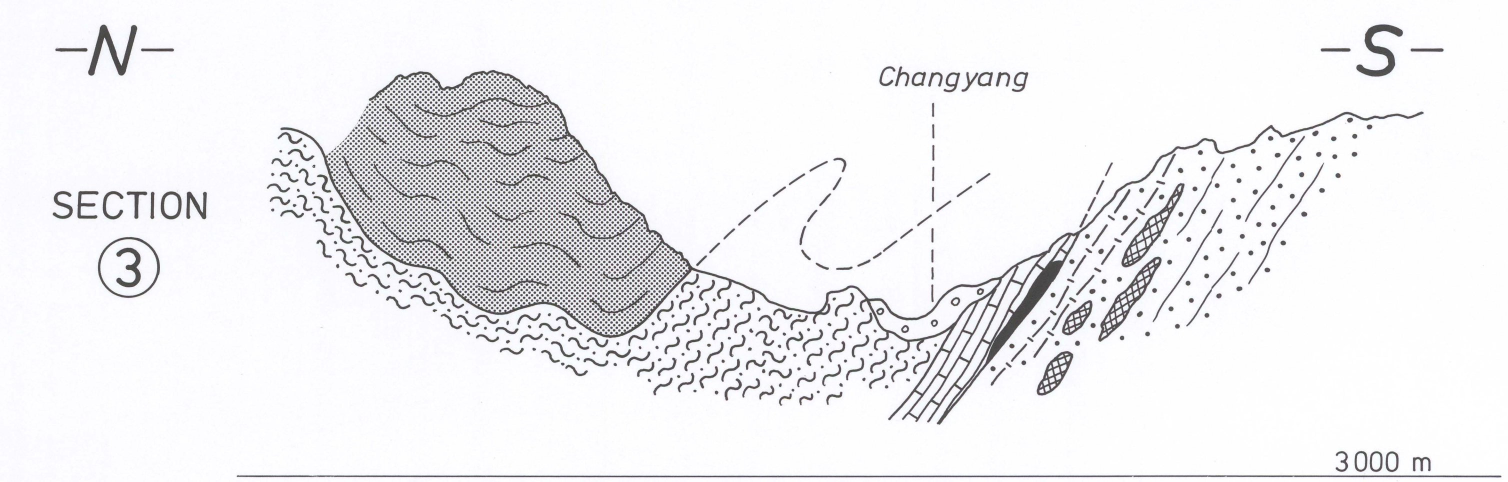


Index

- Glaciers
- Quaternary deposits, mainly moraines
- Manaslu Granite (Miocene)
- Spiti Shales (Up. Jurassic - L. Neocomian)
- Lumachelle Formation (Up. Dogger)
- Kioto Limestone (Rhaetian - L. Dogger)
- Quartzite Series (Rhaetian)
- Tarap Shales (Norian)
- Mukut Limestone (Anisian - Norian)
- Tamba Kurkur Formation (Scythian - Anisian)
- Carbonates, Volcanics, In general – Thini Chu Formation
- Tilicho Pass Formation (Devonian)
- Tilicho Pass Formation, carbonates
- Dark Band Formation (Silurian - L. Devonian)
- North Face Quartzite (Ordovician)
- Nilgiri Limestone (Ordovician)
- Metamorphic carbonates (Central Crystalline)
- Schuppen, scales
- Normal fault (teeth show to down thrown side)
- Anticline
- Syncline
- B-axis, lineation
- Dip 0°- 5°
- Dip 5°- 30°
- Dip 30°- 60°
- Dip 60°- 85°
- Dip 85°- 90°
- •17140 Height in feet
- Camp





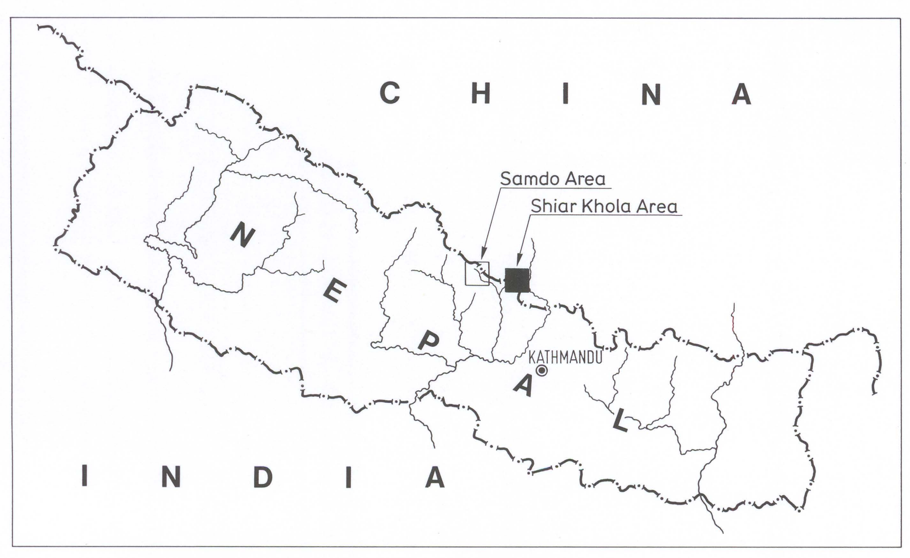


Sections across the upper Shiow Khola area

Scale 1 : 63 360

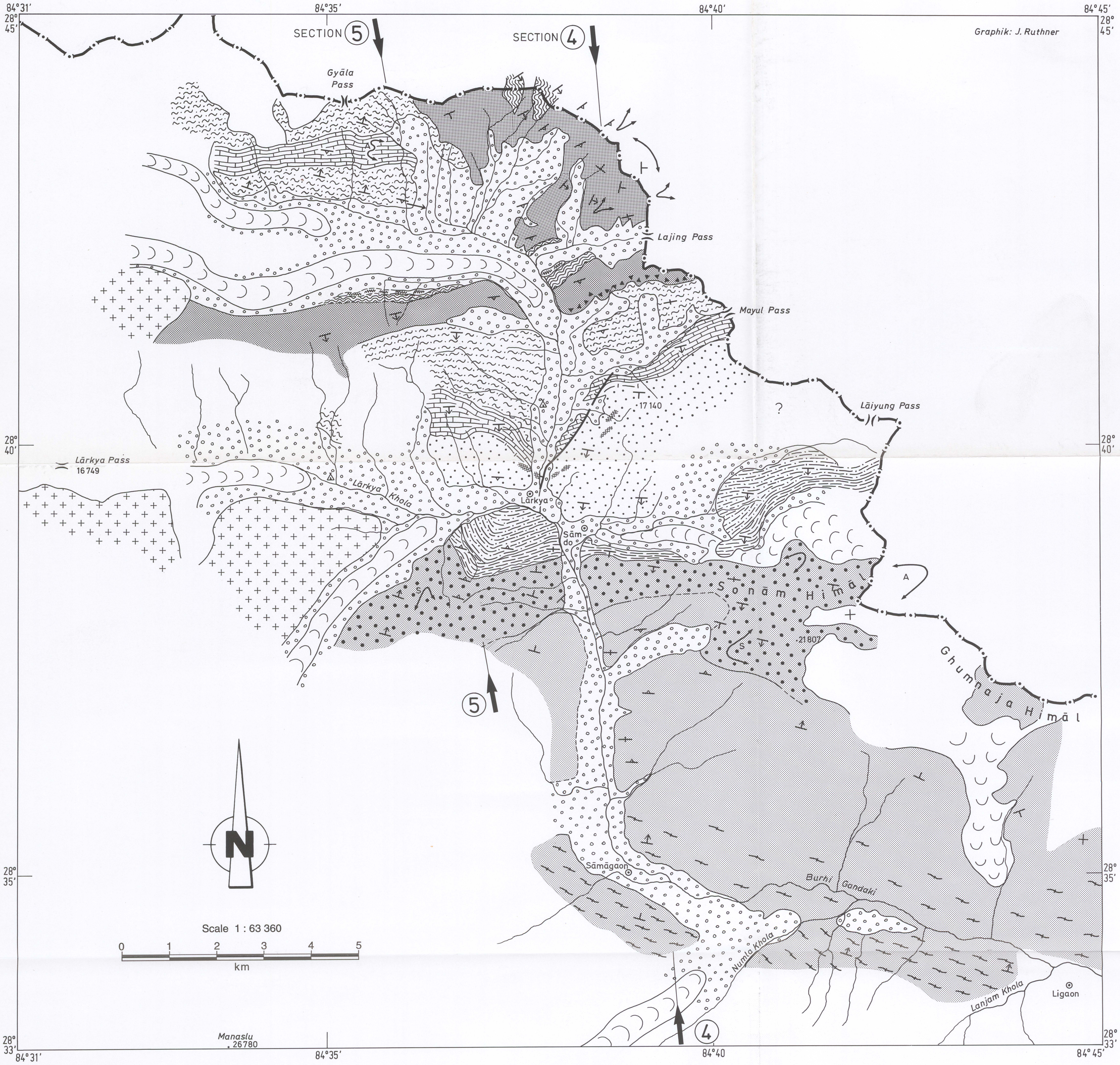
0 1 2 3 4 5 km

Vertical scale slightly exaggerated



Jb. Geol. B.-A., **141**, H. 1, 1998 – Beilage 2
FUCHS, G. & PAUDEL, L.P. – Plate 2

Geological Map of the Samdo area



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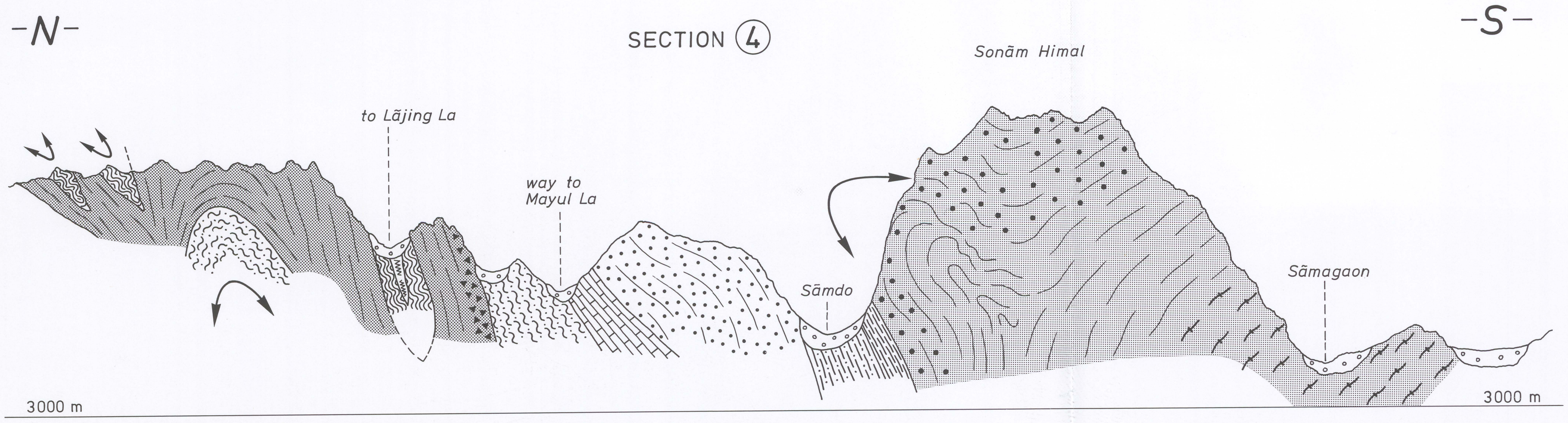

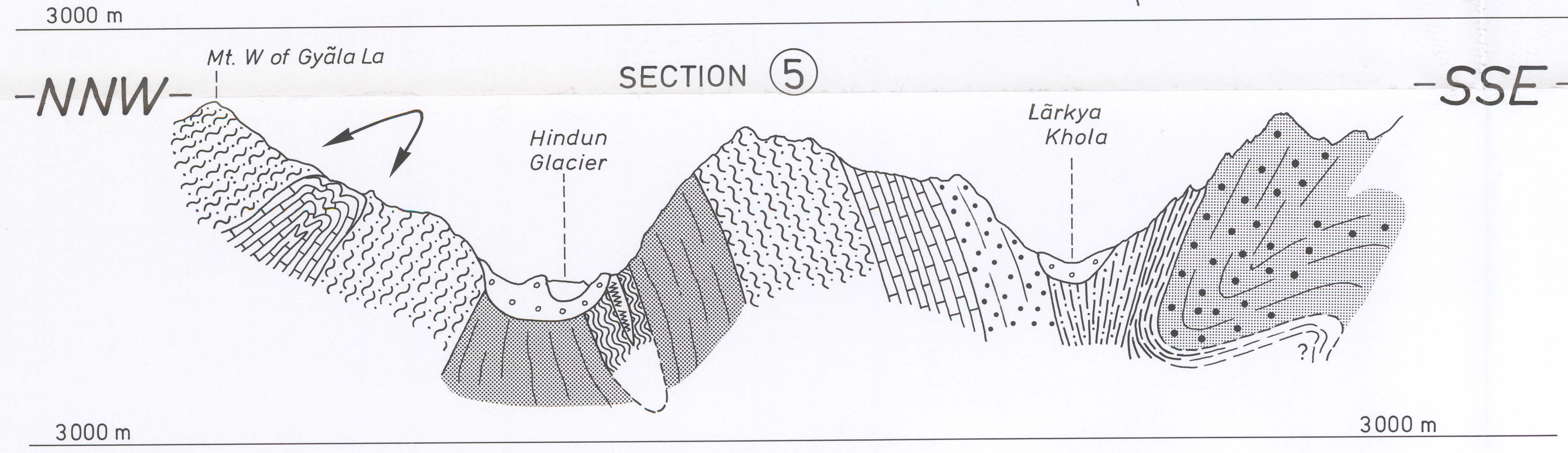

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