| Jb. Geol. B.-A. | ISSN 0016-7800 | Band **131** | Heft 4 | S. 593–607 | Wien, Dezember 1988 |
|---|---|---|---|---|---|

# Contributions to the Geology of the Annapurna Range (Manang Area, Nepal)

By GERHARD FUCHS, RUDOLF W. WIDDER & RAMESH TULADHAR*)

With 9 Figures and 2 Plates

*Nepal*
*Himalaya*
*Annapurna Range*
*Stratigraphy*
*Tectonics*

## Contents



## Zusammenfassung

Im Rahmen geophysikalischer und petrologischer Arbeiten einer deutschen Nepal-Expedition (1987) wurden begleitende geologische Untersuchungen durchgeführt. Diese werden, soweit sie die Tibetische Zone im Gebiet von Manang betreffen, in der vorliegenden Arbeit vorgelegt.

Die Schichtfolge der Tibetischen Zone reicht im untersuchten Gebiet vom kambro-ordovizischen Nilgiri Kalk bis zur Lumachelle Formation des Dogger. Der Bau ist verhältnismäßig einfach: Eine große Mulde mit NW–SE-Achse entlang des Marsyangdi-Tales wird von einer Antiklinale in der N-Flanke der Annapurna-Gruppe überfaltet. Einige Brüche komplizieren den Bau. Die kräftige alpidische Metamorphose, mit Grünschieferfazies im Dogger, hat große Teile der Sedimentfolge erfaßt und damit die Primärmagnetisierung weitgehend ausgelöscht.

*) Authors' addresses: Univ.-Doz. Dr. GERHARD FUCHS, Geologische Bundesanstalt, Rasumofskygasse 23, A-1031 Wien; Dr. RUDOLF W. WIDDER, Institut für Geologie, Universität Wien, Universitätsstraße 7/III, A-1010 Wien; Dr. RAMESH TULADHAR, Geological Survey of Nepal, Lainchaur, Kathmandu, Nepal.

## Abstract

The geophysical and petrological work of the German Expedition 1987 to Nepal was accompanied by geological investigations. Some results of the later are presented in this paper as far as they concern the Tibetan Zone of the Manang area.

There the stratigraphic record ranges from the Central Crystalline up to the Dogger. The tectonics are comparatively simple: a large syncline with the NW–SE axis following the Marsyangdi Valley is overfolded from the S by an anticline exposed in the north face of the Annapurna Range. Some faults cause complication of the structure. The strong Alpine metamorphism affected large portions of the sedimentary sequence too, and thus mostly obliterated the primary magnetization of the rocks.

## Résumé

Les travaux de géophysique et de pétrologie d'une expédition allemande au Népal en 1987 ont été accompagnés d'un relevé géologique, dont sera présenté la partie concernant les séries tibétaines du Nyi Shang.

Dans cette région la zone tibétaine comprend une stratigraphie allant du calcaire du Nilgiri d'âge cambro-ordovicien aux Lumachelle Beds du Dogger.
Les structures sont relativement simples: Une anticlinale dans le flanc nord de l'Annapurna se replie sur une large synclinale élongée selon NW–SE.
Le metamorphisme alpin, avec faciès de schistes verts jusqu'aux séries jurassiques, a affecté la magnetisation primaire.
Les sédiments étudies ont été datés biostratigraphiquement à l'aide de conodontes, très utiles surtout dans ces séries metamorphiques.

# 1. Introduction

In 1987 a German geoscientific expedition carried out palaeomagnetic and petrological research in the Annapurna area of northern Nepal (Fig. 1). For this work we were invited to join the German team and to provide the necessary geological informations.

One of us (FUCHS) previously has worked in the Thakkhola and Dolpo regions adjoining to the W (FUCHS, 1967, 1977) and thus was familiar with the rock formations and tectonics of the Tibetan Zone of northern Nepal. It was his duty to identify the formations and structures around the sites of palaeomagnetic sampling. WIDDER worked out the detailed stratigraphic column at these sites and was mostly concerned with biostratigraphic questions. TULADHAR did the necessary geological measurements and gave special interest to the economic aspects of the area visited.

The monography of the area by BORDET et al. (1975) should provide a sound basis for the named geological work. Soon after the beginning of our field work it turned out, that there were serious mistakes in the work of the French geologists. These inconsistencies are probably caused by the worse circumstances mentioned on p. 14 (l. c.). For us there was a need now to do a geological reconnaissance survey parallel with the palaeomagnetic work. The results of our geological studies are presented in this paper. Our investigations concentrated on the Marsyangdy Valley up to Manang with a cursory trip to the Thorung La.

# 2. Stratigraphy

## 2.1. The Base of the Tibetan Zone

All along the Himalaya the axial core of the mountain belt – the Central Crystalline – is overlain by the Tibetan or Tethys Zone. This sedimentary zone shows a stratigraphic record from the Precambrian up to the Eocene. In the area investigated the sedimentary column ends with the Jurassic.

Like in many other regions of the Himalaya, it is problematic to place the boundary between the crystallines and the succeeding sedimentaries. The metamorphic alteration decreases gradually in the sedimentary sequence from amphibolite facies in the Lower Palaeozoic rocks to greenschist facies in the Jurassic series (MASCH & SCHNEIDER, 1987, p. 26).

A primary transition from the crystalline into the sedimentary series is the rule and only in some areas of the Himalaya the original passage was disturbed by tectonics.

In the Marsyangdi section the transition is perfect. BORDET et al. (1975, p. 23f) regard the augen gneiss of Chame (Formation III) as the top of the Central Crystalline. As the carbonate gneisses (Formation II) are geochemically identical with the Larjung-Mutsog Formation overlying the augen gneisses, they suggest the hypothesis that the Formation III represents the core of a huge recumbent anticline (BORDET et al., p. 44, 45, fig. 23). To us this suggestion appears very probable, because the lithology of the carbonate formations below and above the augen gneisses are rather similar. The first is integrated part of the crystallines, whereas the latter are regarded as the base of the Tibetan Zone. This again stresses the observation that a clear separation of crystallines and sedimentaries is not possible.

The thick succession of marbles and carbonate gneisses W of Chame is correlated by BORDET et al. (1975) to the Larjung Formation of the Kali Gandaki Valley and similarly for this formation a Cambrian (?) age is proposed for the Mutsog-Chame carbonates. FUCHS (1967) regards the Larjung Formation as the high-grade metamorphosed basal portions of the Dhaulagiri Limestone and not as a separate stratigra-


Fig. 1.
Location of the mapped area.

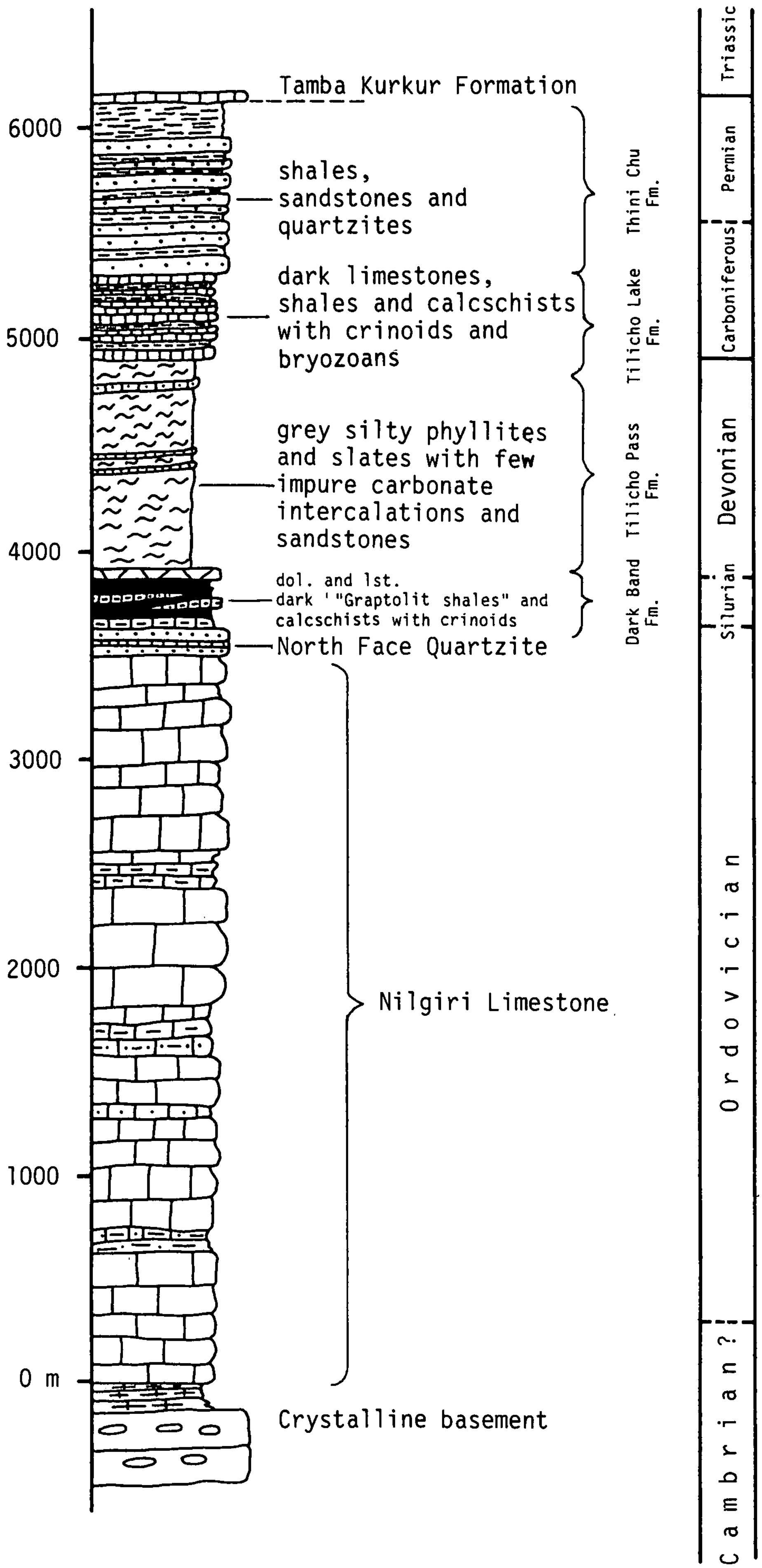



Fig. 2.
Generalized section of the Palaeozoic in the Manang area.

phical unit. In the Barbung Khola, for instance, the alteration reaches much higher levels of the Dhaulagiri Limestone, and thus the major part of this limestone formation could be termed Larjung Formation. Similarly the Nilgiri Limestone is shown comparatively thin in the Marsyangdi area, whereas the Larjung-Mutsog carbonates are very thick (BORDET et al., 1975). Considering the lithology we accept the whole carbonate series as Nilgiri Limestone (correlative to the Dhaulagiri Limestone of Dolpo [FUCHS, 1967]). The lower two thirds of the formation are strongly altered, and the upper portion is showing lower grade of metamorphism.

## 2.2. The Nilgiri Limestone

The whole succession 3000–4000 m thick consists of well-bedded limestones alternating frequently in a rhythmic style with impure pelitic or arenaceous calcareous beds. The lower portions consist of medium to coarse-grained marble containing the lime-silicates diopside, phlogopite, hornblende and layers of biotite-carbonate gneiss and calc-silicate gneiss. Dikes of tourmaline pegmatite (0.2–2 m) are frequent in the carbonate series. Between Chame and the bend of the valley south of Mutsog the crystallinity decreases gradually. Near Mutsog the fine- to medium-grained marbles are predominantly grey and laminated. Layers with sandy to silty impurities are interbedded in a rhythmic pattern. These rocks still contain biotite and in pegmatoid lenticles hornblende and epidote are found. The metamorphic grade is still amphibolite facies.

The upper parts of the Nilgiri Limestone exposed in the area around Pisang consist of well-bedded, blue-grey to rather light grey, finely crystalline limestones with thin pelitic layers. The latter frequently show silky skins of sericite. The grade of metamorphic altertion is still at least greenschist facies.

Regarding the age of the Nilgiri Limestone we could not find additional fossil evidence. Some layers in the upper part of the Nilgiri Limestone are yielding indeterminable, strongly deformed shells of brachiopods. In analogy to the fossiliferous occurrences in the regions to the W (EGELER et al., 1964; FUCHS, 1967; BORDET et al., 1971) it can not be excluded that the basal parts comprize also Cambrian.

Concerning the facies the great thickness and rhythmicity of the impure limestones suggest rich supply of sediment and rapid deposition in a subsiding basin.

BORDET et al. (1975) describe the Pi Formation between their Mutsog Formation and the Nilgiri Limestone. Our work in the area of Pi revealed that such a formation does not exist: The occurrences shown by BORDET et al. (1975) in their map proved to be Nilgiri Limestone (N and NE of Pi), North Face Quartzite (E of Pi), or the Silurian Dark Band Formation SW of Drongkhang.

## 2.3. The North Face Quartzite

EGELER et al. (1964) introduced the name North Face Quartzite for a 560 m series of often calcareous quartzitic arkoses and siltstones. This well-bedded series occurs as a light band above the bluish Nilgiri Limestone. As the arenaceous rocks are interstratified with carbonates lithologically resembling the underlying series, FUCHS (1967) took this light-coloured band as top of his Dhaulagiri Limestone. However it appears appropriate to treat the series as an individual formation, which corresponds to the "Ordovician" of BORDET et al. (1971, 1975). It is a predominantly thick-bedded alternation of very fine-grained to crypto-crystalline quartzites, calcareous, dolomitic or silty quartzites, siliceous limestones and quartzitic schists all of light colours (white, beige, greenish, pink, grey) and blue limestone, partly being siliceous. The rather hard arenaceous rocks exhibit a smooth ochreous weathering surface and break into sharp-edged blocks. The beds are either massive or show faint lamination; cross-bedding and phyllitic layers containing clay galls are not rare. The thickness is 560 m (EGELER et al., 1964) respectively 400 m (BORDET et al., 1971) in the Nilgiri area. BORDET et al. (1975) suggest almost 1000 m for Nyi Shang. We estimate a thickness of only 70–150 m (fig. 3).

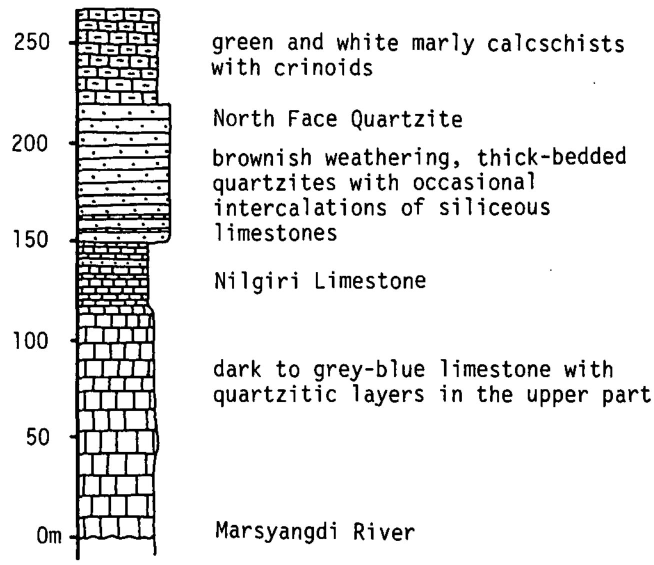



Fig. 3.
The section NW of Gyaru, left side of Marsyangdi River, showing the succession from the upper part of the Nilgiri Limestone to the North Face Quartzite.

Considering the Ordovician fossils in the upper Nilgiri Limestone and the Ordovician brachiopods and crinoids in the succeeding calcschists BORDET et al. (1971) designate the North Face Quartzite as Ordovician.

The facies of the North Face Quartzite indicates an increase of detritic terrigenous matter compared to the Nilgiri Limestone. This may be caused by filling up of the basin and/or beginning tectonism. With the North Face Quartzite the uniform sedimentation of very thick basin formations ends and a variety of facies develops in the Silurian and Devonian.

## 2.4. The Dark Band Formation

The stratigraphy of the series between the North Face Quartzite and the Tilicho Pass Formation is not easy to treat. There are major differences in the lithological development from place to place indicating rapid facies changes and fossils are absent in the Manang area. However some common features can be deduced from sections studied in the Manang area and compared with the Thakkhola and Dolpo regions:

Above the North Face Quartzite light-coloured calcschists and crystalline limestones rich in crinoids follow. In the Thakkhola BORDET et al. (1971) proved an Ordovician age (Llanvirn-Caradocian) of the lithounit. The crinoid carbonates are succeeded by a conspicuous series of black slates, siltstones and carbonates. In this Dark Band Formation EGELER et al. (1964) discovered Silurian graptolites (Llandovery). We find also light-coloured crinoid limestones interstratified with the black slates, so no clear separation is possible. This series is overlain by the silty slates, silt-and sandstones of the Tilicho Pass Formation (Devonian). E of the village Ngawal the black slates come very close to the Lower Carboniferous limestones, which rest on the Tilicho Pass Formation. Therefore we suspect that locally the major part of this formation may be developed in the euxinic facies. BORDET et al. (1971) report that the Silurian/Devonian boundary, lying within the Dark Band Formation, can not be drawn precisely.

We shall describe now a few sections to demonstrate the facies variety in the Manang area:

A) S and SE of Drongkhang (fig. 4): Above the Quaternary terrace deposits we find a banded (dm-m) alternation (1) of black slates, silty slates, black, impure limestones and dolomites, white to lightgrey finecrystalline limestones with some crinoid ossicles. The beds are frequently laminated and nodular. The exposed thickness is 80–120 m. Then follow 10 m of light, schistose crinoid limestone (2) succeeded by 5 m of grey dolomite with rusty weathering (3). The dolomite is overlain by the silty slates of the Tilicho Pass Formation (4).

B) In the cliff W of Drongkhang we find:
   1) North Face Quartzite mostly hidden under talus, outcrops S and SW of the small pass on the trail to Hongde.
   2) Thick-bedded, light green and beige crystalline limestones and calcschists. Siliceous and pelitic layers show sericite and porphyroblasts of biotite; crinoid remains are frequent. Thickness ca. 100 m exposed.
   3) Grey quartzite and argillaceous quartzites with cm-layers of impure carbonate (15–20 m).
   4) Dark grey, fine-grained quartzites (ca. 15 m).
   5) Silty slates (2–3 m).
   6) Finely bedded black slates exhibiting efflorescences (20 m).
   7) Dark grey-green to black, finely laminated silty slates (80 m).
   8) Alternation of dark and light-coloured limestone and some beds of grey quartzite (20 m).
   9) Massive, light grey to white crinoid limestone, partly schistose; remains of Orthoceratid (50 m).

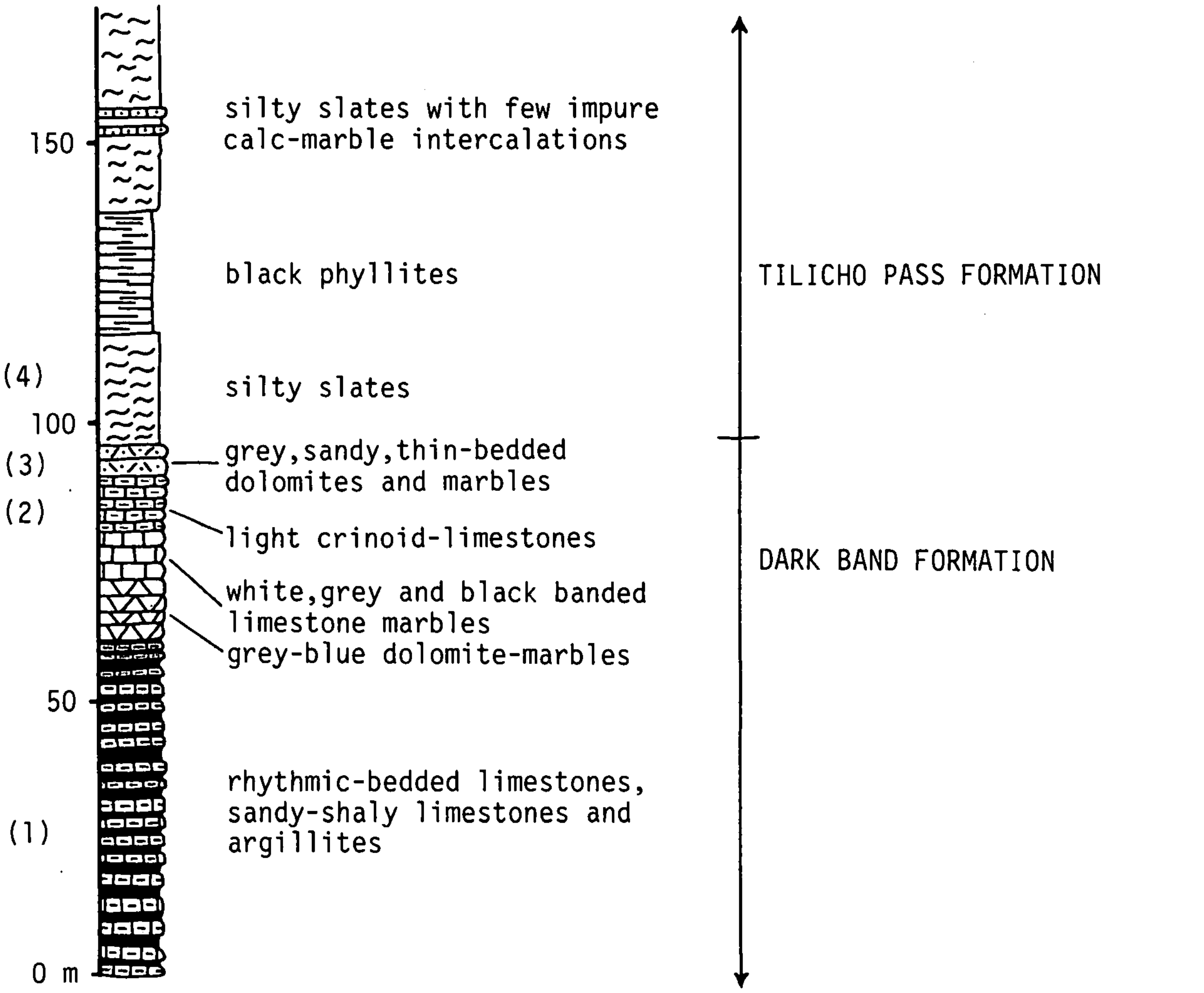



Fig. 4.
Section of the upper Dark Band Formation to the lower Tilicho Pass Formation; cliff 500 m SE Dronkhang.

The boundary to the succeeding Tilicho Pass Formation was not crossed.

C) The outcrop between the river and the track to Hongde NW of Dronkhang belongs to the same series: White, cream, grey crystalline limestone alternating with argillaceous, now sericitc layers and some beds of purple, cream, and white banded quartzite and limestones. The carbonates contain black crinoid ossicles and remains of a gastropod.

SW of the village Gyaru (fig. 3) the North Face Quartzite is overlain by white to greenish sericitic schistose marls and limestones. The rocks are rich in indeterminable crinoids. These calc-schists are succeeded by black slates and green-grey finely laminated silty slates. Sericite on the s-planes indicates the alteration of the series. This seems to explain why our search for graptolites was unsuccessful. Thick beds of rusty weathering carbonate quartzite and limestone are interbedded in the black slates near their lower boundary.

In the syncline (near the desolate monastery) 100–200 m of the black slates are exposed – no younger beds were observed there. The upper boundary of the Dark Band Formation was studied in a section SE of Hongde:

The upper band of dark slates and limestones is succeeded by grey, fine-grained, dolomitic limestone and light crystalline crinoid limestone (30–40 m). This unit corresponds with the section of the cliff W of Drongkhang. Then follows an alternation of impure green and cream carbonates, grey-green phyllites, silt- and sandstones, which represent a passage into the Tilicho Pass Formation. This transition zone is 50–60 m thick.

Regarding the age of the described series it is important that BORDET et al. (1971) found an Ordovician fauna in the crinoid schists following the North Face Quartzite. STRACHAN et al. (1964) and EGELER et al. (1964) were the first to report about a Llandoverian graptolite fauna from the lower part of the Dark Band Formation. BORDET et al. (1971) gave further proof of Llandoverian graptolite zones, but found also Lower Devonian fossils in the black carbonates and schists of the upper portion of the Dark Band Formation.

Thus we expect that in the Manang area too the crinoid bearing calcschists overlying the North Face Quartzite are still Ordovician. The calcschists interbedded with the dark slates, however, are Silurian with much certainty. We also must be aware that possibly, like in the Thakkhola, the upper part of the Dark Band Formation is Lower Devonian.

We have taken a lot of samples from the carbonates of this formation for microfossils, especially for conodonts; however they did not contain any fossils, except a few crinoids without stratigraphic value. Because of the slaty cleavage and transversal schistosity it seems to be improbable to discover such fragile fossils like graptolites. Such fossils have been found in the less altered equivalent sections of the Thakkhola by BORDET et al. (1971). Some fragments of deformed macrofossils (brachiopods, *Orthoceras* sp.) have been found in the profile 2 km WNW Pisang.

As to the facies we find much variation from section to section in the Manang area. After the shallow water deposition of the North Face Quartzite subsidence led to euxinic conditions. The basin facies is intertonguing with the crinoid rich carbonates derived from the nearby shelf. It should be noted that the euxinic facies is replaced by varicoloured shallow-water sediments towards the W (western Dolpo [FUCHS, 1977]).

## 2.5. The Tilicho Pass Formation

EGELER et al. (1964) introduced this name for a 900 m sequence of sandstones, siltstones, and argillites exhibiting sedimentary structures commonly found in turbiditic successions.

In the Manang area the series exhibits its typical lithology: grey to black slates, phyllites, silty micaceous slates to siltstones commonly laminated, fine- to medium-grained sandstones, mostly as cm- to dm-layers in the silty slates. Occasionally we find quartzitic sandstones, carbonate quartzites and quartzites of grey, green, rarely white colour, occurring as m-beds; the arenacous rocks show often rusty weathering. Frequently the silty and arenaceous layers are irregular, swelling up and down or being lenticular. Bioglyphs, burrows, flute casts, rill- and tool marks, as well as the lithology remind of a turbidite sequence, which was already recorded by EGELER et al. (1964), FUCHS (1967), BORDET et al. (1971), BODENHAUSEN & EGELER (1971). Portions of the formation are prevailing silty-argillaceous, others more arenaceous. How far this variation is vertical or lateral is not easy to decide in the much disturbed series. Occasionally we find carbonate intercalations: SE of Drongkhang dirty grey, finely stratified, crinoid bearing limestones occur in the basal part of the formation.

In the area Chheraji Khola thin- to thick-bedded grey, blue, pink, cream and beige carbonates are interstratified. They are impure silty limestones, limestones and dolomitic limestones. This carbonate zone, which is exposed in 50–60 m thickness, seems to occur in the middle portions of the formation; these beds yielded a conodont fauna documenting an Upper Devonian (Frasnian) age:

Sample 44/7 at site 44 (identification by H. SCHÖNLAUB, Vienna):
*Ancyrodella curvata* (BRANSON & MEHL)
*Icriodus* sp.
*Polygnathus linguiformis* HINDE
*Polygnathus* sp.
*Palmatolepis* sp.

Somewhat higher in the same section we find a banded alternation of dark laminated slates and grey, green, cream coloured crinoid limestones. The carbonate beds attain 10–30 cm thickness and show graded bedding in some cases.

In the valley SW of Drongkhang a conspicuous varicoloured horizon occurs in the upper parts of the formation. Ochreous weathering layers of green, grey and cream carbonate quartzite, dolomite and limestone alternate with green and grey phyllites. Some layers are mottled brown-green reflecting an irregular distribution of carbonate and organic matter. The horizon yielded a lower Upper Devonian (Frasnian) conodont fauna (det. Univ.-Doz. Dr. H. P. SCHÖNLAUB):

Sample F6 (2 km SW Drongkhang):
*Ancyrodella nodosa* ULRICH & BASSLER
*Icriodus* cf. *nodosus* ULRICH & BASSLER
*Palmatolepis* sp.

*Polygnathus* cf. *webbi* STAUFFER
*Polygnathus* cf. *linguiformis* HINDE.

In the Thakkhola and Dolpo regions the Devonian age of the Tilicho Pass Formation was documented by conodonts, brachipods and corals (FUCHS, 1967; FUCHS & MOSTLER, 1969; BORDET et al., 1971). In the Manang area BORDET et al. (1975) mentioned the occurrence of *tentaculites* in certain horizons of their Bangba Formation (synonym of the Tilicho Pass Fm.).

The Tilicho Pass Formation is a predominantly pelitic-silty-arenaceous complex of several hundred, but possibly up to 1000 m thickness. There was rich supply in terrigenous matter, which was deposited in a subsiding basin, partly under turbiditic conditions. The carbonate intercalations seem to be derived from adjoining shelf areas by turbidity currents, grain flow and similar ways of transport. In Dolpo the basin facies passes into outer, inner shelf and litoral facies towards the W. In the Manang area it appears that locally (e. g. NE Ngawal) the euxinic facies persisted from the Silurian not only into the Lower Devonian, but rather throughout the Devonian. Black slates occur very close to the Lower Carboniferous limestones in the named area. But we did not a continuous mapping of the Gyaru-Ngawal area and thus there remains some uncertainty.

## 2.6. The Tilicho Lake Formation

EGELER et al. (1964) termed the formation Ice Lake Formation. BORDET et al. (1971) used the geographical name of this lake, which is in agreement with the code of nomenclature. BORDET et al. (1975) introduced the new term "Bangba Gompa Formation", which however is ill-defined. In the Marsyangdi Valley the formation is composed of grey, blue and black, fine-grained to dense limestones, marly limestones, calcschists and dark grey to black shales. This sequence is thin- to thick-bedded with even or nodular s-planes. Not rarely the rocks are laminated. Weathered carbonates frequently exhibit ochreous surface. Crinoid stems and ossicles (up to 1 cm in diameter) are very common. Other fossils are bryozoa (fenestellids), brachiopods, corals and bivalves.

Sample 34 (Site 34; 2.7 km NW Ngawal; identification kindly by Prof. Dr. F. M. KINNEY, North Carolina):
? *Polypora*
*Spinofenestella*
*Productus* sp.

Sample 35/5 (3 km NW Ngawal):
Rhabdomesidae
*Fenestella*
*Spinofenestella*
Goniocladiidae
*Utropora*
*Protoretepora*

At the site 40 (Sample Nr. 40/9, 1 km ESE Munji) a small ammonite fauna could be collected from grey, finely crystalline limestones, however was too badly preserved for determination.

Compared to Dolpo the fossil content of the formation is poor and ill-preserved. But some of our samples yielded conodonts which are in agreement with the generally accepted Lower Carboniferous age of the formation (det. kindly by Doz. Dr. H. P. SCHÖNLAUB, Geol. B.-A., Vienna):

Sample 30/1 (Site 30):
*Gnathodus* cf. *typicus* COOPER

Sample 32 (Site 32):
*Gnathodus* sp.

BODENHAUSEN & EGELER (1971) and BORDET et al. (1975) point to the abundance of fenestellids in the prevailingly shaly topmost part of the formation.

Regarding the facies of the Lower Carboniferous it is noticeably consistent from Nepal to Kashmir. The lithology and the character of the fossils suggests deposition in badly aerated water of a restricted carbonate shelf.

## 2.7. The Thini Chu Formation

Also this name was introduced by EGELER et al. (1964). BORDET et al. (1975) traced the formation from the Thakkhola to Manang and stressed that from there further eastwards the character changes. Therefore they used the name Chulu Formation.

The formation consists of thick beds of white, grey and green quartzites and sandstones, mostly medium- to coarse-grained, alternating with grey-green to black slates and silty slates. There are also brown weathering carbonate sandstones and quartzites. Cross-bedding and clay gall breccias indicate deposition in shallow water. Conglomeratic layers and the occurrence of coal in the Thakkhola (BORDET et al., 1971) suggest a litoral environment. The formation is generally rich in plants, corals, bryozoans, brachiopods, cephalopods, bivalves, trilobites and crinoids. In the Manang area fossils are relatively rare and ill-preserved. E of Manang BORDET et al. (1975) discovered tilloids and a spilite horizon. According to these authors these beds mark a biostratigraphic hiatus. The lower parts of the formation are regarded upper Lower to Middle Car-

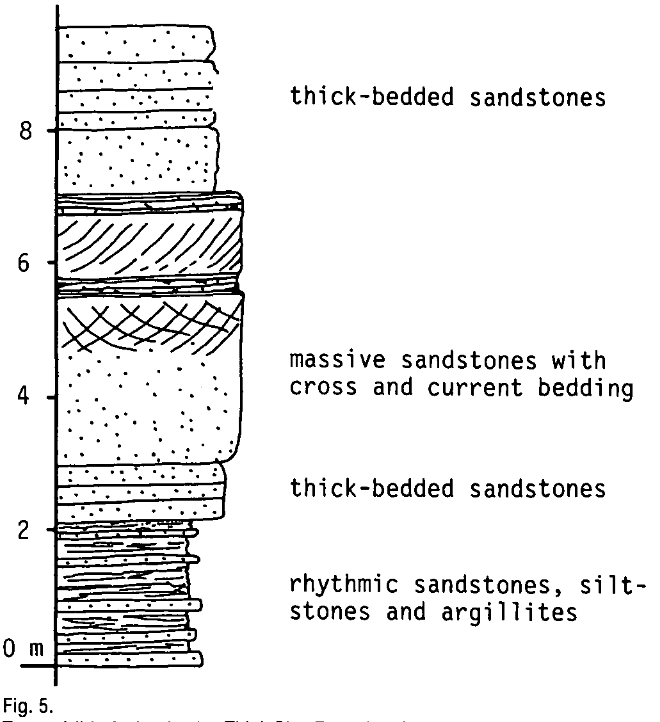



Fig. 5.
Type of lithofacies in the Thini Chu Fomation 3 km W Hongde.

boniferous, the upper portions as Permian. This means that the Thini Chu Formation has a larger stratigraphic range in the Thakkhola and Manang areas (BORDET et al., 1971, 1975) than in Dolpo. In the later region it is late Middle to Upper Permian, whereas in the E it also comprises portions of the Carboniferous apparently correlative to the Fenestella Shales of the NW-Himalayas. The thickness of the formation 700–900 m in the Manang area ist also much larger than in eastern (80–300 m) and western Dolpo (30–70 m).

Thus the Upper Palaeozoic gap so wide-spread in the Himalayas is larger towards the W. Like in many other parts of the Himalaya the uppermost portions of the Permian formations consist of dark silty slates, known as Productus Shales, Kuling Shales etc. In the Manang area such silty argillites are underlying the conspicuous limestone band of the Tamba Kurkur Formation.

## 2.8. The Tamba Kurkur Formation

In previous papers FUCHS referred to the conspicuous limestone band at the base of the Triassic series as "Scythian" (FUCHS, 1967, 1977). However it turned out that this lithounit comprises also Anisian and may reach even into the Lower Ladinian (KRYSTYN, pers. comm. in FUCHS, 1982). Therefore the term established by SRIKANTIA et al. (1980) in the NW-Himalaya is used here.

The formation is an excellent marker horizon, a rusty weathering resistant band of 20–30 m thickness. It is composed of thin-bedded, frequently nodular light grey, brownish, or blue limestones (classification after FOLK [1959, 1962]: biomicrite-biosparite; DUNHAM [1962]: bioclastic wackestone) with subordinate layers of grey shale. The limestones are rather dense and certain beds are rich in ammonites. Several of our samples yielded conodonts.

Near the eremitage NE of Manang the Tamba Kurkur Formation is ca. 20 m thick. From the lowest 1 m the samples 47/1–3 are derived (fig. 6, det. L. KRYSTYN):

47/1: *Neospathodus* cf. *dieneri* SWEET

47/2: *N. dieneri* SWEET
*N. cristagalli* (HUCKRIEDE)

47/3: *N. dieneri* SWEET
*N. cristagalli* (HUCKRIEDE)
*N. nepalensis* (KOZUR & MOSTLER)
*N.* cf. *pakistanensis* SWEET
In thin sections of this sample were observed: ammonites, foraminifera, filaments, gastropods, echinoderms, and ostracoda (*Monoceratina* sp.);
Age: Dienerian/Smithian boundary (*N. pakistanensis* zone after T. MATSUDA [1985, p. 158]).

The Griesbachian is not documented by fossils in our section. The lower half of the formation is platey whereas the upper one is thick-bedded.

Sample 48 was taken from the top of this upper division. It contained:

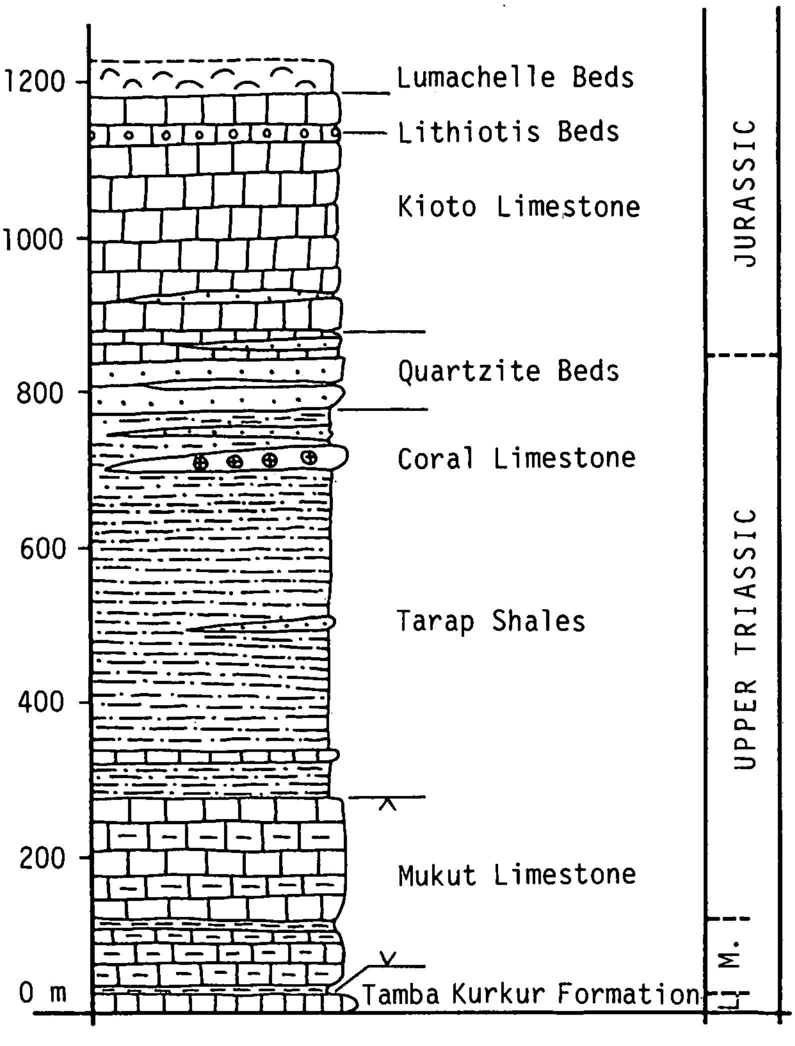



Fig. 6.
Generalized section of the Mesozoic in the Manang area.

*Neospathodus timorensis* (NOGAMI)
*Gladigondolella tethydis* (HUCKRIEDE)
Age: Lower Anisian

Thus the Tamba Kurkur Formation comprises the Scythian and Lower Anisian in the Manang area.

The Tamba Kurkur Formation is a pelagic series without terrigenous influx. Some beds full of ammonites appear to be condensed sediments. There is no doubt that the sea has further widened and deepened after the deposition of the Thini Chu Formation. In one section of eastern Dolpo FUCHS (1967) described a passage from the Permian into the Scythian within one thick bed of limestone. But in most localities there is a slight gap indicated by missing biozones (WATERHOUSE, 1976) respectively a thin ferruginous layer (FUCHS, 1977), BORDET et al. (1975, p. 92) record a passage from the Permian to the Triassic, which we are not able to confirm due to the scarcity of observations.

## 2.9. The Mukut Limestone

EGELER et al. (1964) named the whole Triassic complex up to the base of the Quartzite Beds "Thinigaon Formation". FUCHS (1967) subdivided the Triassic series into the Lower Triassic limestone band, the calcareous-argillaceous Mukut Limestone and the Tarap Shales. KRYSTYN (1982) studied the ammonite zones in the Upper Triassic of the Thakkhola and subdivided into the Mukut Limestone s. str. (Upper Ladinian–Lowest Carnic), Thinigaon Formation (Carnic–Lowest Noric) and Tarap Formation (Noric). We do not follow this suggestion and use the term Mukut Limestone in the sense of FUCHS for the whole calcareous-argillaceous complex. First it is confusing to use the already existing terms Mukut Limestone and Thinigaon Formation in a changed sense. Second it seems impossible in geological mapping to trace the "formations" of KRYSTYN. Outcrops are often discontinuous, the formation is intricately folded and fossils occur sporadic. So it may be hard to decide only on the basis of lithology between the Mukut Limestone s. str. and the Upper Thinigaon Formation.

The Mukut Limestone consists of dark grey to blue limestones, marly limestones and dark grey to black shales. This alternation is predominantly thin-bedded, occasionally we find m-bedding. There are zones dominantly calcareous and others more argillaceous (e. g. KRYSTYNS Lower Thinigaon Fm.). Some limestone beds weather in ochreous colour. Due to bleaching the dark rocks give a scree conspicuous by its light colour and easily traceable in the field. Fine lamination of the limestones and nodular s-planes are common. In Dolpo the fossil content, mainly ammonites, brachiopods, bivalves, crinoid and others indicated Middle Anisian to Lowest Noric age (FUCHS, 1977; FUCHS & MOSTLER, 1969).

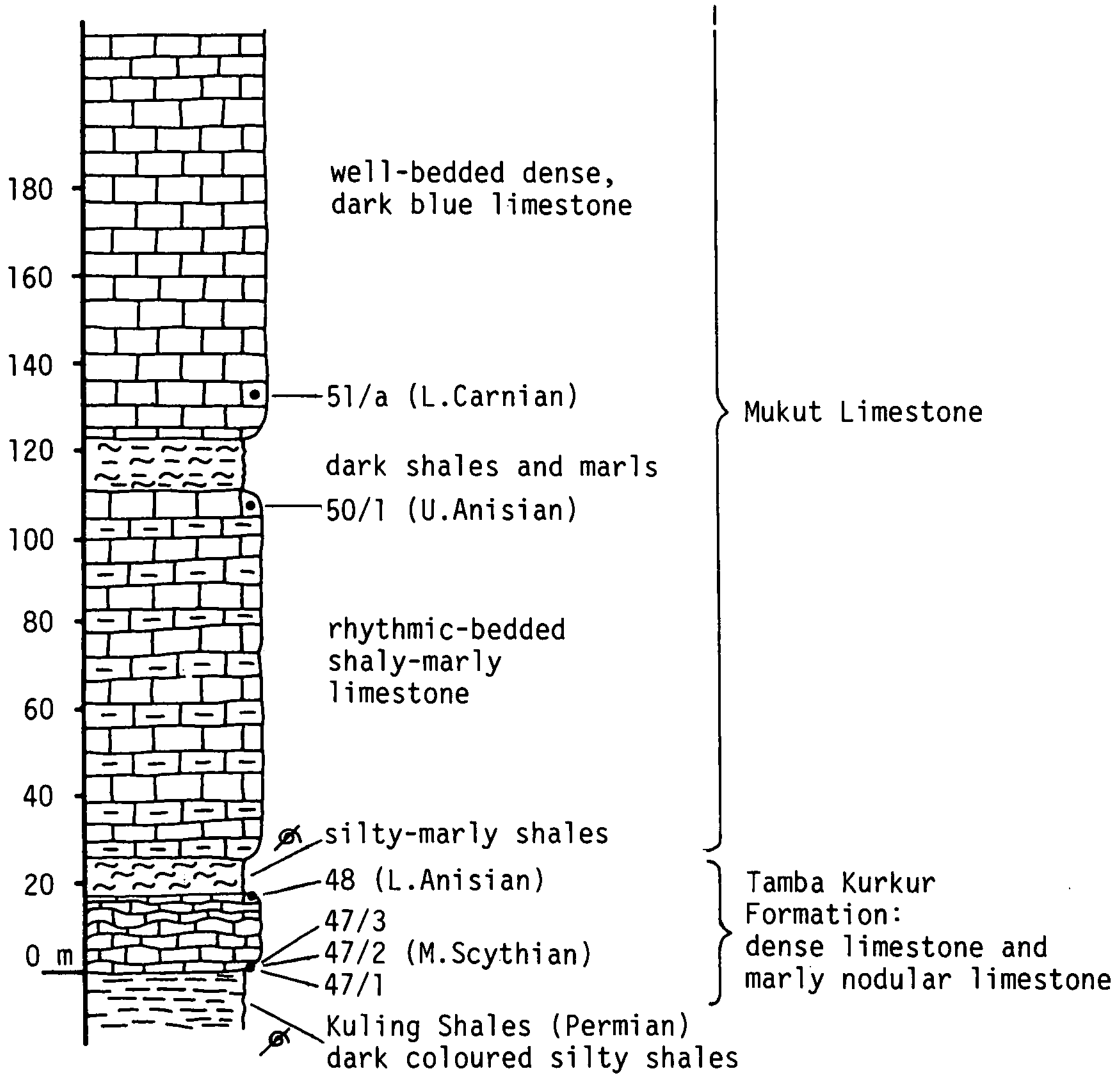



Fig. 7.
Section of the Lower to Middle Triassic, 1 km NE Manang.

Near Manang some of our samples yielded conodonts. In the already mentioned section NE of Manang (fig. 7) the sample 50/1 taken 90 m above the base contained:

*Gondolella* cf. *constricta* MOSHER & CLARK
*Gladigondolella tethydis* (HUCKRIEDE)

giving an Upper Anisian age.

30 m above sample 50/1 a small pyritized ammonite was found in dense blue limestone, indicating Lower Carnian age:

*Badiotites eryx* (MÜNSTER)
(det. kindly by Doz. Dr. L. KRYSTYN).

Sample 55/6 from the trail to Thorung La, approximately 2.5 km NW of Manang, yielded a Lower Carnian (Jul) conodont fauna out of black dense limestones, interbedded with grey silty marls:

*Gondolella inclinata* KOVACS
*Gondolella polygnathiformis* BUDUROV & STEVANOV
*Gladigondolella* –ME

The facies of the Mukut Limestone indicates sedimentation in poorly aerated deeper water of outer shelf. Only argillaceous material reached the area of deposition, silty influx is exceptional (FUCHS, 1967; 180–181). We observed two silty argillaceous intercalations of a few meters thickness in the section above Manang (fig. 7).

Towards the top of the formation the shales become dirty green-grey and silty, the limestones are still blue, but impure by silty matter. From the valley W of Churi Lattar a loose specimen of

*Gonionotites italicus* GEMM.

was derived and stresses its uppermost Carnian age (Tuval 3/II). This and the previous determinations by L. KRYSTYN show that the change from calcareous to silty arenaceous sedimentation occurred in the Lower Noric (KRYSTYN in FUCHS, 1977). This change can be followed from Nepal to Eastern Ladakh).

## 2.10. The Tarap Shales and Coral Limestone

The formation is composed of dark grey to green, silty shales, siltstones and impure sandstones. Flute casts, graded bedding, tool marks, burrows, trace fossils like *Zoophycus* give the formation a turbiditic character (FUCHS, 1967, 1977; BODENHAUSEN & EGELER, 1971, p. 534). Black concretions in the shales are common. Occasionally there are also impure calcareous rocks in the series. Fossils like ammonites, brachiopods, bivalves and gastropods are rather rare (BORDET et al., 1971; FUCHS, 1977). The thickness of the Tarap Shales is estimated 400–600 m in the Manang area.

A very conspicuous limestone horizon was discovered on the trail SE of Churi Lattar and WNW of this place. In the latter locality the ordinary Tarap Shales are overlain by thick beds of carbonate sandstone, red, white and green crinoid limestone, grey schistose limestone and green, fine-grained, micaceous sandstone. The arenaceous rocks occasionally show current bedding. The above series is ca. 40 m thick and is succeeded by about 70 m of silty shales and sandstones – the normal development of the Tarap Shales. Then the Tarap Shales pass into the Quartzite Beds by alternation.

SE of Churi Lattar Tarap Shales are followed by a ca. 120 m thick alternation of silty shales, micaceous sandstone, carbonate sandstone, grey and red crinoidal limestone. These beds are succeeded by thick-bedded, pink, grey and white coral limestone of a few meters thickness. The colonies and stems of the corals are in situ as well as some layers of broken and reworked fossils occur in the sequence.

Microfacies and fossil content of selected samples from the Coral Limestone (sampled in the area 2 km SSE Churi Lattar):

- **Samples F13, 13a, 13b**
  Red and grey, massive, coral-rich limestones.
- Classification
  FOLK, 1959, 1962: biolithite
  DUNHAM, 1962: bafflestone-framestone
  PLUMLEY et al., 1962: Energy Index V/3
  WILSON, 1975: SMF-Type 7; FZ 5
  Generally 50–80 Vol.-% biogens in Fe-free micritic matrix; only exceptionally secondary dolomitization of the matrix.
- Fossils
  (identification by P. RIEDEL/Erlangen):
  *Parathecosmilia sellae* (STOPPANI)
  *Retiophyllia clathrata* (EMMRICH)
  *Astraeomorpha crassisepta* REUSS
  *"Sphinctozoa"* gen. et sp. indet.
  *Spongiomorpha ramosa* FRECH
  *Parachaetetes* sp.
  echinoides, hydrozoans, ostracoda, filaments;

From the sample F13 some corals could be determined by Doz. Dr. E. KRISTAN-TOLLMANN/Vienna as *Montlivaltia* sp. and ? *Montlivaltia marmorea* (FRECH).

According to the mentioned fauna, RIEDEL supposes a Norian to Rhaetian age.

The Coral Limestone is followed by a series like the one described from below and then probably after crossing a fault, Tarap Shales crop out.

There ist no doubt that the carbonates represent a stratigraphic intercalation in the Tarap Shales. The Coral Limestone s. str. seems to have a rather restricted extent, because corals were not observed in the sections WNW of Churi Lattar. A comparable carbonate horizon was hitherto unknown from Nepal – it was neither found in Dolpo nor in the Thakkhola. However in Spiti the Coral Limestone occurs between the Juvavites and Monotis Shales of Noric age (HAYDEN, 1904; DIENER, 1912; FUCHS, 1982). The Coral Limestone of Spiti is thicker than the Nepal occurrence, it attains 30 m. The Mid-Noric reefs of Spiti were also restricted as indicated by their areal distribution; apparently the reefs developed on small areas, which were almost free of the detritus that contaminated the surrounding parts of the basin. The sills seem to have existed for a relatively short period in the Middle Noric. In Nepal the conditions for the growth of a patch reef appear to have been much more an exception than in Spiti. As to the facies of the Tarap Shales there is a marked rhythmic influx of silty-arenaceous matter.

Such increase in the supply of land derived detritus in the Noric is found throughout the Tibetan Zone from Nepal to Ladakh. In western Ladakh and Kashmir shallow water carbonates persist throughout the Triassic. We favour the view that the sedimentation occurred in deeper water in the central and eastern parts of the Tibetan Zone. The scarcity of carbonates in Nepal shows that the production of carbonates has markedly decreased since the deposition of the Mukut Limestone. The sedimentary structures suggest the occasional activity of turbidity currents, which needs a somewhat deeper basin.

At the top the Tarap Shales pass into the Quartzite Beds by alternation. Obviously the supply in arenaceous matter increases. This is explained as a regression in the uppermost Noric and Rhaetic, which can be traced from Nepal to Kashmir.

## 2.11. The Quartzite Beds and Kioto Limestone

Above the sombre coloured Tarap Shales the thick-bedded, light-dark-banded Quartzite Beds represent a marker horizon in the landscape. They are composed of white, grey, green, brown and blackish, fine- to coarse-grained quartzites, carbonate quartzites, carbonate sandstones, blue to grey carbonates and subordinate green shales. In this alternation current bedding, clay gall breccias, burrows and pipes of worms are common. The thickness varies around 50 m.

The carbonates of the Quartzite Beds are of Kioto-type and by decrease of the arenaceous beds there is a passage into the Kioto Limestone. Light to dark grey, blue limestones and dolomites are predominant rocks. The dolomites are mostly secondary dolomites. Oolites, pelletal structures, intraformational breccias and layers composed of biodebris stress the shallow water character of the formation. Fossils are algae, corals, bryozoans, brachiopods, foraminifera, pelecypods, gastropods and crinoids. Shell beds of *Megalodon* in the Triassic parts, *Lithiotis* in the Liassic portions are characteristic.

From the known fossil-content and the under- and overlying series a Rhaetic to Lower Dogger age appears well-established for the Quartzite Beds – Kioto Limestone sequence (300–400 m). GUPTA (1976) stresses a beginning of the Quartzite Beds already in the uppermost Noric. The Middle Liassic age is shown by the occurrence of *Orbitopsella praecursor* (Sample 58/9, fig. 8) in the lower part of the Kioto Limestone.

Microfacies of selected samples from the Kioto Limestone (fig. 8)

○ **Sample 58**

Kioto Limestone; red oolitic crinoid limestone from the basal section of a massive limestone bed.

Classification

FOLK, 1959, 1962: oomicrite
DUNHAM, 1962: bioclastic packstone
PLUMLEY et al., 1962: Energy Index IV/I
WILSON, 1975: SMF-Type 15; FZ6

The composition is like in sample 58/9, however the texture is strongly different because of considerable deformation of the particles.

○ **Sample 58/9**

Kioto Limestone; pale pink to light grey, taken from the central part of a massive limestone bed.

Classification

FOLK, 1959, 1962: oosparite
DUNHAM, 1962: bioclastic grainstone
PLUMLEY et al., 1962: Energy Index IV/I
WILSON, 1975: SMF-Type 15; FZ6

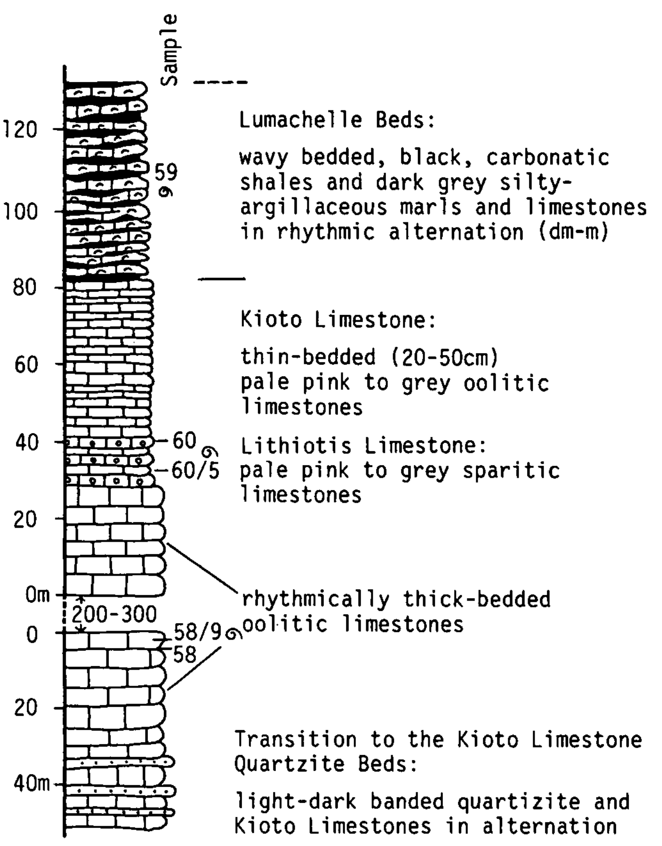



Fig. 8.
Compiled section from the Quartzite Beds/Kioto Limestone transition up to the Lumachelle Beds, established in the valley 8 km SSE of the Thorung La.

Very well sorted and rounded carbonate particles in a sparitic matrix; cement consits of Fe-free sparite, only few dolomitic grains are visible (partly as nucleus of ooids).

Particles: Abundant partly to entirely micritized ooids; aggregate grains, peloids, cortoids and bioclasts; losely packed; slightly deformed by metamorphism.

Bioclasts: Foraminifera e. g. *Orbitopsella praecursor* (GÜMBEL), *Lituosepta* sp. *Lenticulina* sp.; gastropods, echinoid-spine, crinoids, algae;

Age: Middle Liassic (established by the occurrence of *Orbitopsella praecursor*; L. HOTTINGER, 1967, 1971).

○ **Sample 60**

Kioto Limestone-Lithiotis Beds; light to dark grey lumachelle limestone

Classification

FOLK, 1959, 1962: biosparite
DUNHAM, 1962: bioclastic grainstone
PLUMLEY et al., 1962: Energy Index III/3
WILSON, 1975: SMF-Type 12; FZ6.

Pelecypod coquina with sparitic matrix; the pelecypods show a considerable boudinization and are entirely recrystallized under conditions of greenschist facies. In literature this stratigraphic section in the upper part of the Kioto Limestone is known as "Lithiotis Beds" because of the abundant occurrence of these pelecypods.

Particles: aggregate grains, peloids

Bioclasts: pelecypods (Lithiotis), algae, foraminifera.

Fig. 9.
Two sections of *Orbitopsella praecursor* (GÜMBEL) in bioclastic grainstone of the lower Kioto Limestone showing the Middle Liassic age of the sample.
Location of sampling (59/8): Valley 8 km SSE of Thorung La; length of section: 8 mm.

○ **Sample 60/5**
Kioto Limestone-Lithiotis Beds
Classification
FOLK, 1959, 1962: biointrasparite
DUNHAM, 1962: grainstone with aggregate grains
PLUMLEY et al., 1962: Energy Index IV/2
WILSON, 1975: SMF-Type 17: FZ7/8
Densely packed, well-rounded carbonatic particles in a sparitic matrix. The cement consists of a Fe-poor calcite with less than 1 Vol.-% dolomite. The particles (average size 0.5 mm) are generally micritized; peloids and aggregate grains most common; few ooids and bioclasts: foraminifera, filaments, gastropods, echinoids; sorting is moderate.

The microfacies shows that the Kioto Limestone has been deposited in a sedimentary environment of an inner shelf area (FZ6–8 after WILSON, 1975) with very warm shallow water, moderate to restricted circulation and tidal flats.

### 2.12. The Lumachelle Formation

This formation was found only in one occurrence in the course of our 1987 survey: In the overturned syncline of the valley NW of Churi Lattar the highly contorted series forms the core of the syncline faulted against Quartzite Beds (Pl. 1, 2 (1)). There we observed black shales with thin layers of ochreous weathering, blue sandstone, arenaceous limestone and micaceous limestone. Bivalves, crinoids and belemnites are the only ill-preserved fossils. Burrows are common.

The age of the Lumachelle Formation is generally accepted as Bajocian-Bathonian (upper Middle Jurassic; FUCHS, 1967; BORDET et al., 1971). The formation grades from the Kioto Limestone and is succeeded by a conspicuous ferruginous bed of Callovian age (BORDET et al., 1971), which, however, was not observed in the course of our mapping.

### 2.13. The Quaternary Deposits

Like in many other regions N of the Great Himalayan Range we find thick Quaternary deposits in the Manang area.

First there are several landslides, which have dammed up the Marsyangdi. From the western face of Mutsog huge rock masses have slipped down along a W-plunging s-plane of the ending syncline. Upstream from this rock slide the river accumulated thick fluvio-lacustrine deposits in the area of Pisang. This village is situated on another rock mass, which has slumped from the northern side of the valley. Also this landslide occurred in a dip slope.

The thick landslide mass WNW of Drongkhang came down from the Gyaru side. It caused the accumulation of thick Quaternary deposits. They are exposed on both sides of the valley between Hongde and Manang. These fluvio-glacial sequences are ill-sorted and mostly unstratified. They weather in steep rock faces. Flowing water has washed out crevasses and gorges and led to the formation of rock towers. The result is a wild scenery.

The glaciers coming down from the Great Himalayan Range reached the Marsyangdi in some places (opposite of the villages Munji and Manang). Forests developed on the moraines of these glaciers, but from the well-preserved forms of the moraines it appears, that this glacial event occurred in the last century. The lake of Manang is caused by burried ice of the frontal parts of the Gangapurna Glacier, which have molten away.

Also upstream of Manang thick fluvio-glacial deposits are found along the Marsyangdi and the Jarsgeng Khola.

We did no special investigation of the Quaternary deposits, but a detailed survey would show systems of moraines and fluvial terraces.

## 3. Tectonics

It is a characteristic of the Tibetan Zone that the dominant structures are folds of varying vergency. Only where higher nappes have overridden the Tibetan Zone (e. g. Kumaun, Spongtang in Ladakh) the direction of the folding is uniform towards the SW. Locally small scale thrusts and imbrications are observed. The passage zone between the Central Crystalline and the sedimentaries is sometimes disturbed by gravitational downslip of the sedimentary sequence from the crystallines (BURG, 1983). However nappe tectonics are absent from the Tibetan Zone – contrary to the assumptions of BAUD et al. (1982, 1984) and GAETANI et al. (1985, 1986).

### 3.1. Folds

In the Manang area the structure is particularly simple. It consists, roughly speaking, of a large syncline along the Marsyangdi Valley and an anticline in the north face of the Annapurna-Nilgiri Range. This anticline is overturned to the north. The N-directed anticline in the north face of the Great Himalaya Range and the adjoining syncline continue towards the W in the Dhaulagiri and Kanjiroba Groups (FUCHS, 1967, 1977).

The high grade metamorphosed carbonates of Chame dip towards WNW to WSW at gentle to medium angles (pl. 1). In the Mutsog area the dip increases to medium angles and the strike swings around from NW to N–S and NW again. The rocky west face of the Mutsog with ca. 1500 m vertical difference represents a huge s-plane demonstrating the strike in a conspicuous way (fig. 8). In the Mutsog the WNW plunging dip slope marks the SE-end of the Manang Syncline.

The NE-limb of the Manang Syncline from the Mutsog to near Gyaru is built by Nilgiri Limestone. Just E of the village Pisang there is an outcrop of North Face Quartzite. At medium to steep angles the well-bedded Nilgiri Limestone sequence forms the orographic left flanks of the Marsyangdi Valley. It can be seen to reach up right to the crest of the Pisang Tse. We doubt that a syncline of Silurian rocks builds up this mountain as shown in the map by BORDET et al. (1975).

In the SW-flank of the Manang-Syncline the Nilgiri Limestone strikes from the Mutsog up to the NE-spur of the Annapurna II. There the dip is predominantly steep NE and the beds show wavy folding (pl. 2/4). In the peak of Annapurna II the dip seems to become SW but we do not expect younger formations there like the French geologists do.

The core of the Manang Syncline is formed by the Devonian Tilicho Pass Formation building up the hills SE and S of Drongkhang. In the first place the dip is prevailing SW, whereas in the second the beds are steeply and tightly folded with dips mostly vertical. The French geologists have overlooked this Devonian syncline, which we were able to prove by fossil evidence in the valley SW of Drongkhang (sample F6).

In the ridge W of the named valley the next younger formation comes in – the Lower Carboniferous Tilicho Lake Formation. The syncline is formed by the normal succession Nilgiri Limestone – North Face Quartzite – Dark Band Formation – Tilicho Pass Formation and Tilicho Lake Formation. The French map is completely inconsistent with the geology of that area.

Further W in the Sabje Khola small bodies of the Thini Chu Formation are exposed in the core of the syncline. The Tilicho Lake Formation is intricately folded. The folds are directed NNE. From the Sabje Khola towards the W to S of Manang the SW-flank of the Manang Syncline is overturned towards the NNE. In the northern slopes of the Marsyangdi Valley the Nilgiri Limestone is succeeded by the North Face Quartzite at Gyaru. W of that village crinoid schists and black slates of the Dark Band Formation follow. The series are much folded, but predominantly dip towards the SW at medium angles.

In the area Ngawal – Chheraje Khola we get into younger formations: the Tilicho Pass and Tilicho Lake Formations. Near the village Ngawal 3 isolated occurrences of the Lower Carboniferous limestones rest on the Devonian slates and siltstones. They mark a synclinal axis.

In the Chheraji Khola the Lower Carboniferous limestones are succeeded by the Permo-Carboniferous Thini Chu Formation, which dips towards the SW at gentle to medium angles. They represent the NE-limb of the wide syncline of Manang (pl. 1, 2/3).

N of Mungji and Manang Triassic series form the core of the syncline (pl. 1, 2/3, 4). Whereas the NE-limb shows SW-dip at low to medium angles, the SW-flank of the Manang Syncline is overturned and intricately folded. This can be observed in the Khangsar – Jargeng Khola area (pl. 1, 2/1, 2).

SW of the Chulu peaks a secondary anticline complicates the NE-flank of the Manang Syncline. It brings up the Upper Palaeozoic Thini Chu Formation. Along the trail to Thorung La the Tarap Shales on the orographic right side of the valley N of Churi Lattar mark the core of this anticline. There is tight folding of Quartzite Beds and Kioto Limestone in the SW-limb of the anticline.

The youngest beds met in the course of this survey are the Mid Jurassic Lumachelle Beds. WNW of Churi Lattar the series crops out as a narrow band, faulted between Kioto Limestone and Quartzite Beds. The Permian to Dogger sequence is inverted there and represents the SW-limb of the Manang Syncline.

We did not map in the region further W of Manang but on the basis of EGELER et al. (1964), BORDET et al. (1971, 1975) and our observations from afar the main traits of the structure are rather clear: The gigantic NE-directed anticline of the Annapurna Massif continues in the Nilgiri, Dhaulagiri (FUCHS, 1967) and Kanjiroba Groups (FUCHS, 1977). The limb connecting this anticline and the Manang Syncline generally is overturned towards the NE. Whereas this syncline forms one simple synform downstream from Manang, it becomes more complicated towards the W: At least 3 synclines develop separated by minor anticlines.

### 3.2. Faults

As shown in the last chapter folds are the predominant structures in the Manang region. At a much minor degree faults were active. BORDET et al. (1975) assumed a series of NE–SW-trending faults to explain the apparent discontinuation of formations and structural elements (see their map). Our mapping showed that the geological elements are very much persistent and that there is no need for the assumption of faults. Nevertheless, several faults may be observed.

The NNE–SSW striking fault W of Gyaru, which was already found by the French geologists, brings up Nilgiri Limestone beneath the North Face Quartzite. Apparently the Silurian series W of that fault are downthrown.

A NNW–SSE trending fault crosses the lower Chheraji Khola and complicates the structure. The local folding in the Lower Carboniferous limestones does not fit on the opposite sides of the valley. The block W of the fault obviously is upthrown, Tilicho Pass Formation is brought to the surface and abuts against the limestones of the Tilicho Lake Formation in the E.

In the steep slope above Manang two faults with a displacement of a few meters can be seen from afar. Contrary to the French geologists the eastern side is downthrown along these faults.

A major fault crosses the Jarsgeng Valley in the NW–SE-direction and it took us some time to understand this structure. The rock series to the SW of the fault are downthrown (pl. 1, 2/1). Therefore rather horizontal Tarap Shales abut against Mukut Limestone in the tributary valley SE of Churi Lattar. Further NW the fault cuts the overturned synform consisting of Coral Limestone, Tarap Shales, Quartzite Beds and Kioto Limestone. The syncline is cut almost parallel to its axis and near its apex. Further NW the Dogger in the core of the overturned syncline has come into contact with the Quartzite Beds along this fault. In areas dominated by Kioto Limestone faults parallel to the strike of rocks are very common (FUCHS, 1967; 1977).

## 4. Economic Aspects

We could not give any desired attention to search for mineral deposits of economic interest during the course of this investigation due to time constraint. However, it is worthwile to mention certain facts in this regard:

a) There are frequent occurrences of pegmatitic pockets within the Crystalline rocks (gneisses and marbles) of Manang; some of them contain gem-quality beryl and tourmaline (verified from local people). They are similar to those of gem-bearing pegmatites within the Crystalline Nappes (Phakuwa Group) of the Lesser Himalaya in East Nepal. The pegmatites consist of intergrowths of quartz and feldspars (largely microcline and albite) with books of micas (biotite, muscovite and lepidolite). Besides beryl and tourmaline, even the rare mineral corrundum (ruby) is reported (pers. comm. MASKEY, N. Q., 1988) to occur in such pegmatitic veins.

b) A NaCl-bearing hot-spring occurs few hundred meters north of Bahundanda. Its position close to the MCT and the nature of occurrence suggest it to be a local hot-spring related to tectonics as in other parts of Nepal rather than to the overlying Tibetan sediments.

c) Encrustations of Cu-sulfphide are observed in the quartzitic rocks of the upper portion of the Thini Chu Formation (Permian) which contains few spilite horizons. It indicates possible occurrence of some volcano-sedimentary sulphide mineralization within the Tibetan sedimentary sequence. Favorable tectonic setting and deposition environment for such mineralization in the Palaeo-Tethys basin are probable.

d) Except for the unfavorable locations, there are several horizons of good quality limestones in the area investigated, that can be used for manufacturing cement.

### Acknowledgements

The authors would like to express their thanks to the DFG (Deutsche Forschungsgemeinschaft) for the sponsorship of the expedition (Project "Paläomagnetik Nepal DFG AZ AP 34/1").

The Austrian "Ministerium für Wissenschaft und Forschung" granted leave to FUCHS enabling so his participation on the expedition. His application for leave was supported by the Director of the Geologische Bundesanstalt HR Prof. Dr. T. E. GATTINGER. FUCHS is very much obliged for all this help.

The kind permission to carry out the field-work in Nepal by the National Council of Science and Technology in agreement with the Department of Mines and Geology is much appreciated.

For the kind determination of the often badly preserved fossils and for advice and help in various ways we are much indebted to Dipl. geol. R. RIEDEL (Inst. of Palaeont. Erlangen, W-Germany), U. Triassic corals in thin sections; Prof. F. K. MC KINNEY (Dept. of Geology, Appalachian State Univ., North Carolina, USA) Carboniferous bryozoans; Doz. Dr. E. KRISTAN-TOLLMANN (Vienna), corals of the U. Triassic, Triassic microfossils in thin sections; Doz. Dr. L. KRYSTYN (Inst. of Palaeont. Vienna), Triassic ammonites and conodonts; Doz. Dr. H. P. SCHÖNLAUB (Geological Survey of Austria, Vienna), Palaeozoic conodonts.

For the possibility to use the laboratory facilities of the Inst. of Geology, Univ. Vienna and for laboratory work, done by the Geological Survey of Austria, we have to give special thanks.

### References

BAUD, A., GAETANI, M., FOIS, E., GARZANTI, D., NICORA, A. & TINTORI, A.: Les Series Tibetaines de l'Himalaya sont-elles allochthones: Nouvelles observations dans le Zanskar Oriental (Inde du N). – Vol. IX RAST, p. 1, Paris 1982.

BAUD, A., GAETANI, M., GARZANTI, E., FOIS, E., NICORA, A. & TINTORI, A.: Geological observations in southeastern Zanskar and adjacent Lahul area (northwestern Himalaya). – Eclogae Geol. Helv.., **77**/1, 171–179, Basle 1984.

BODENHAUSEN, J. W. A. & EGELER, C. G.: On the Geology of the upper Kali Gandaki Valley, Nepalese Himalayas. – Koninkl. Nederl. Akademie Van Wetenschappen, **74**/5, 526–546, Amsterdam 1971.

BORDET, P., COLCHEN, M., KRUMMENACHER, D., LE FORT, P., MOUTERDE, R. & REMY, M.: Recherches Géologiques dans l'Himalaya du Nepal, région de la Thakhola. – Centr. Nat. Rech. Sc., 279 p., Paris 1971.

BORDET, P., COLCHEN, M. & LE FORT, P.: Recherches géologiques dans l'Himalaya du Népal, région du Nyi-Shang. – Cent. Nat. Rech. Sci., 138 p., Paris 1975.

BURG, J. P.: Tectogenèse comparée de deux segments de chaîne de collision: Le sud du Tibet (Suture du Tsangpo) – La chaîne Hercynienne en Europe (Sutures du Massif Central). – Diss. Univ. des Sciences et Techn. Languedoc, Montpellier 1983.

DIENER, C.: The Trias of the Himalayas. – Mem. G. S. I., **36**/3, 1–159, Calcutta 1912.

DUNHAM, R. J.: Classification of carbonate rocks according to depositional texture. – Mem. Amer. Ass. Petrol. Geol., **1**, 108–121, 7 Taf., Tulsa 1962.

EGELER, C. G., BODENHAUSEN, J. W. A., DE BOOY, T., NIJHUIS, H. J.: On the geology of Central West Nepal – a preliminary note. – 22nd Int. Geol. Congr. India 1964, Pt. 11, 101–122, New Delhi 1964.

FOLK, R. L.: Practical Petrographic classification of Limestones. – Amer. Ass. Petrol. Geol. Bull., **43**/1, 1–38, Tulsa 1959.

FOLK, R. L.: Spectral subdivision of limestone types. – Mem. Amer. Ass. Petrol. Geol., **1**, 62–84, Tulsa 1962.

FUCHS, G.: Zum Bau des Himalaya. – Denkschr. Österr. Akad. Wiss., math.-naturw. Kl., **113**, 1–211, Wien 1967.

FUCHS, G.: The Geology of the Karnali and Dolpo Regions, Western Nepal. – Jb. Geol. B.-A., **120**/2, 165–217, Wien 1977.

FUCHS, G.: The Geology of the Pin Valley in Spiti, H. P., India. – Jb. Geol. B.-A., **124**/2, 325–359, Wien 1982.

FUCHS, G. & MOSTLER, H.: Mikrofaunen aus der Tibet-Zone, Himalaya. – Verh. Geol. B.-A., **1969**/2, 133–143, Wien 1969.

GAETANI, M., CASNEDI, R., FOIS, E., GARZANTI, E., JADOUL, F., NICORA, A. & TINTORI, A.: Stratigraphy on the Tethys Himalaya in Zanskar, Ladakh. – Riv. It. Paleont. Strat., **91**/4, 443–478, Milano 1986.

GAETANI, M., GARZANTI, E. & JADOUL, F.: Main structural elements of Zanskar, NW Himalaya (India). – Rend. Soc. Geol. It., v. **8**, 3–8, Rome 1985.

GUPTA, V. J.: The Stratigraphic Position of the Kioto Limestone of Himalaya. – Colloqu. Intern. du C. N. R. S. No. 268 – Ecologie et Géologie de l'Himalaya, 193–196, Paris 1976.

HAYDEN, H. H.: The geology of Spiti, with part of Bashahr and Rupshu. – Mem. G. S. I., **36**/1, 1–129, Calcutta 1904.

HOTTINGER, L.: Foraminifères imperforés du Mésozoique marocain. – Notes et Mém. Serv. Géol. Maroc, **209**, 1295, Rabat 1967.

HOTTINGER, L.: Larger foraminifera of the Mediterranean Jurassic and their stratigraphic use. – Ann. Inst. Geol. Publ. Hungar., **54**/2, 497–504, Budapest 1971.

KRYSTYN, L.: Obertriassische Ammonoideen aus dem Zentralnepalesischen Himalaya. – Abh. Geol. B.-A., **36**, 63 p., Wien 1982.

MASCH, L. & SCHNEIDER, Ch.: Regionalmetamorphose Nepal. – Unpubl. Arbeitsbericht, Inst. f. Petrologie, Univ. München, 27 p., München 1987.

MATSUDA, T.: Late Permian to early Triassic conodont paleobiogeography in the "Tethys Realm". – In: K. NAKAZAWA & J. M. DICKINS (edit.): The Tethys, 157–170, Tokyo (Tokai Univ. Press) 1985.

PLUMLEY, W. J., RISLEY, G. A., GRAVERS, R. W. & KALEY, M. E.: Energy index for limestone interpretation and classification. – Mem. Amer. Ass. Petrol. Geol., **1**, 85–107, Tulsa 1962.

SRIKANTIA, S. V., GANESAN, T. M., RAO, R. N., SINHA, P. K. & TIRKEY, B.: Geology of Zanskar Area, Ladakh, Himalaya. – Himal. Geol., **8**/2, 1009–1033, Dehra Dun 1980.

STRACHAN, I., BODENHAUSEN, J. W. A., DE BOOY, T. & EGELER, C. G.: Graptolites in the "Tibetan Zone" of the Nepalese Himalayas. – Geologie en Mijnbouw 8, **43**, 380–382, Amsterdam 1964.

WATERHOUSE, J. B.: The Permian Rocks and Faunas of Dolpo, North-West Nepal. – Colloqu. intern. du C. N. R. S. No. 268 – Ecologie et Géologie de l'Himalaya, 479–496, Paris 1976.

WILSON, J. L.: Carbonate Facies in Geologic History. – XIII+471 p., Berlin (Springer) 1975.

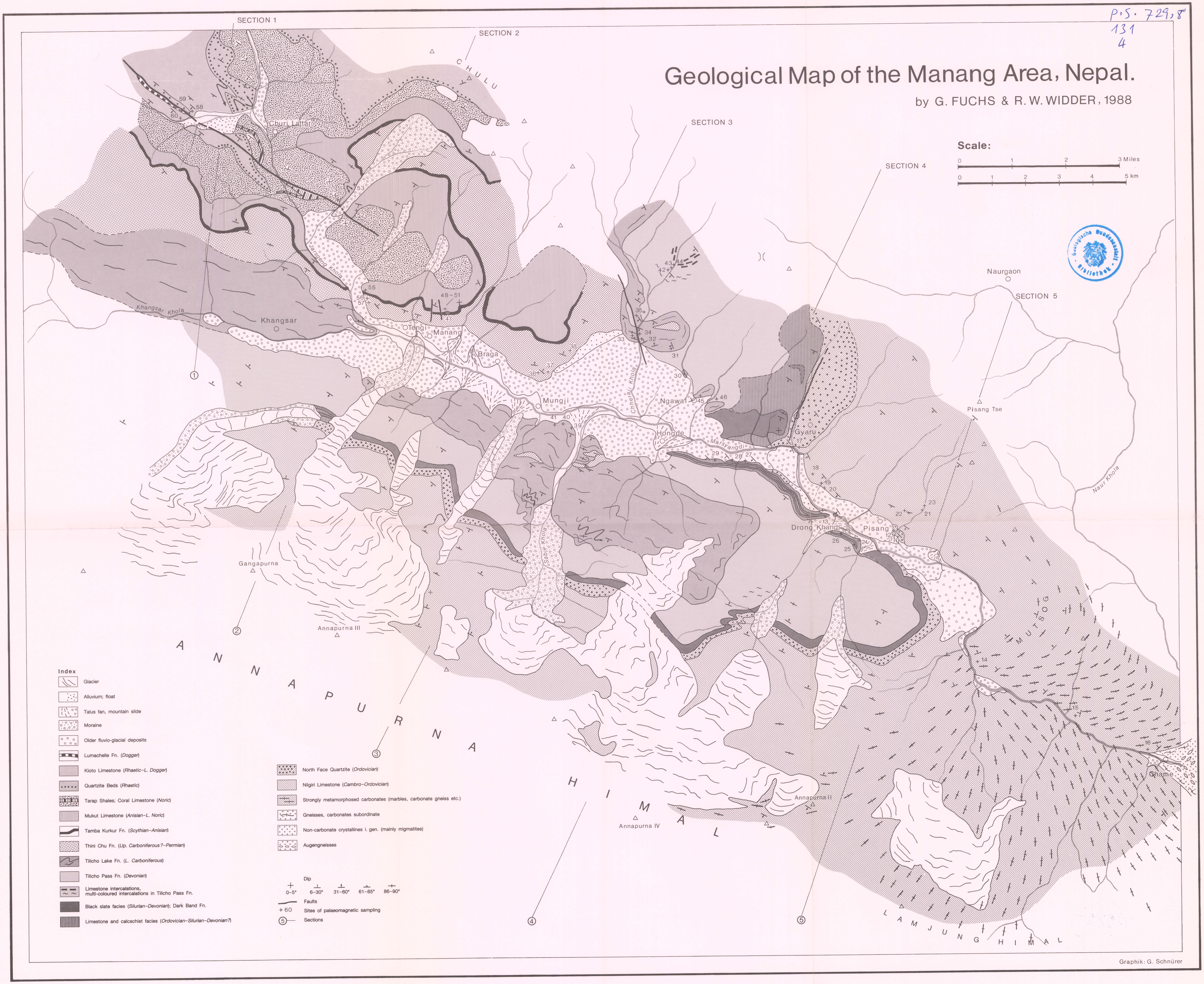
Manuskript bei der Schriftleitung eingelangt am 23. September 1988.

Jb. Geol. B.A., **131**, H. 4, 1988 – Beilage 1
G. Fuchs, R.W. Widder & R. Tuladhar – Plate 1



# Geological Map of the Manang Area, Nepal.

by G. FUCHS & R.W. WIDDER, 1988

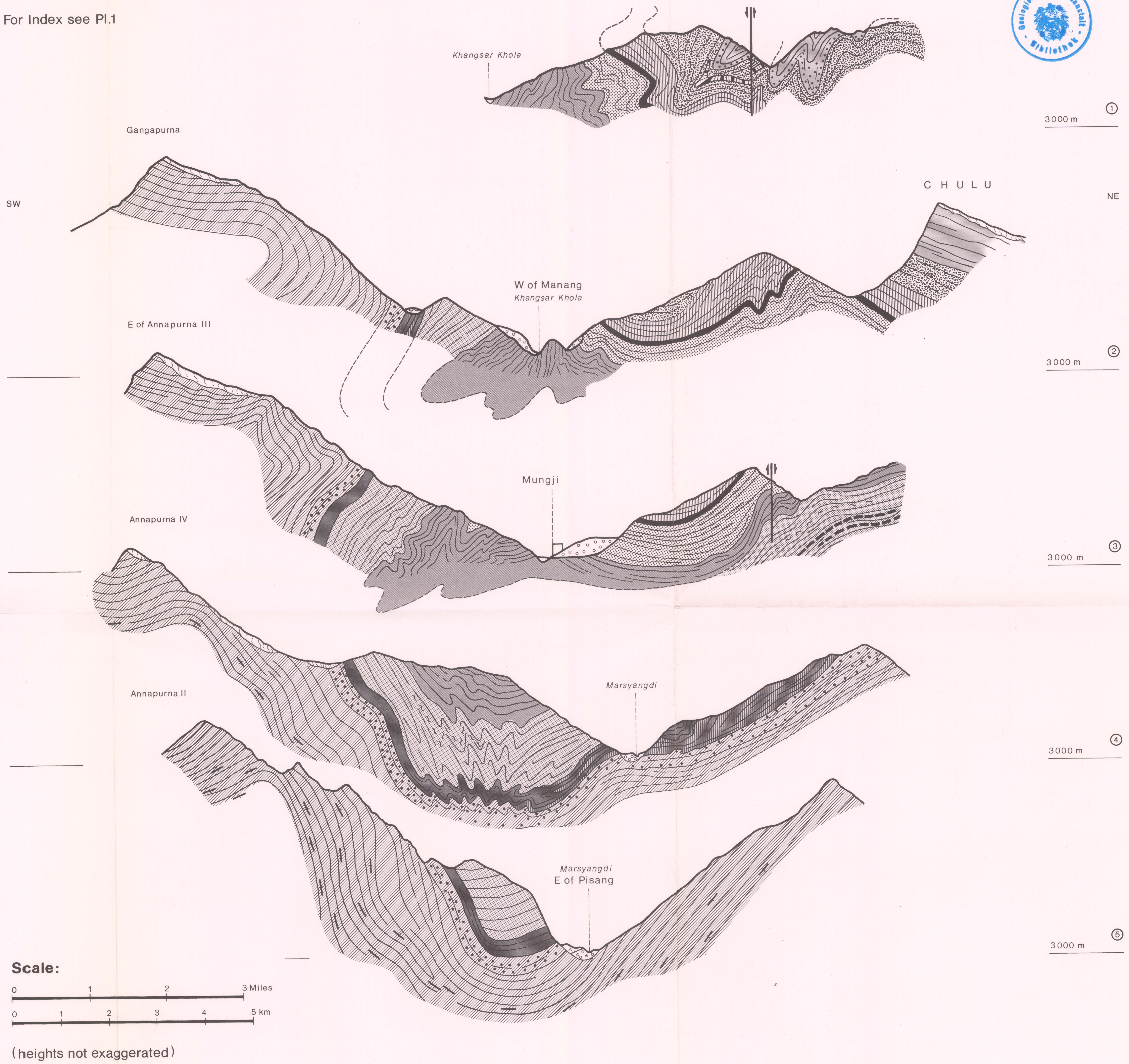


# Geological Sections across the Manang Area, Nepal.

by G. FUCHS & R. W. WIDDER, 1988

For Index see Pl.1






Graphik: G. Schnürer