Mitteilungen der Geologischen Gesellschaft in Wien
66.—67. Band, 1973/74

On the Geology of the Karnali and Dolpo Regions, West Nepal

By GERHARD FUCHS*), **)

With 3 figures

ZUSAMMENFASSUNG

An Hand von Profilen werden der Bau des Karnali-Gebietes und der westliche Teil der Tibetischen Zone von Dolpo beschrieben. Unsere bisherigen Untersuchungen in W-Nepal (FUCHS, 1967; FUCHS und FRANK, 1970) werden damit gegen W ausgedehnt.

Die der Siwalik-Zone aufgeschobene, Tansing-Einheit ist stark reduziert, da die Chail- und Kristallin-Decken eine ausgedehnte Deckscholle bilden. Nördlich derselben sind die Chail-Decken im Galwa-Fenster wieder aufgeschlossen. Dank der gesicherten Schichtfolge ist der komplizierte Innenbau des Fensters aufzulösen. Das Kristallin, welches das Galwa-Fenster umrahmt, wird beim Anmarsch zur Tibetischen Zone von Dolpo gequert.

Die Schichtfolge der Tibetischen Zone von W-Dolpo ist ein wichtiges Bindeglied für die Korrelierung zwischen Nepal und Kumaon und läßt zahlreiche fazielle Veränderungen verfolgen.

Unsere Ergebnisse zeigen erneut, daß die geologischen Einheiten im Himalaya über enorme Entfernungen im Streichen verfolgbar sind. Bei der sich täglich mehrenden Fülle an Detailbeobachtungen ist ein zusammenfassendes vereinheitlichendes Denken mehr denn je notwendig.

INTRODUCTION

Since 1963 the author works on the geology of the Himalayas, his investigations concentrating on western Nepal (FUCHS, 1967; FUCHS and FRANK, 1970). It was the aim of the Austrian Geological Himalayan Expedition 1973 to extend our geological investigations from the Kali Gandaki — Thulo Bheri regions towards the W to the Karnali River and to map the western part of the Tethys Zone in Dolpo (see fig. 1). Though the elaboration of our material is at the beginning, a series of results may be presented yet.

*) Anschrift des Verfassers: Dr. GERHARD FUCHS, Geologische Bundesanstalt Wien, A-1031, Postfach 154.

**) Vortrag, gehalten in der Geologischen Gesellschaft am 8. März 1974.

The first part of the paper deals with the structural-stratigraphic units of the Lower Himalayas, in the second part the Tibetan (Tethys-) Zone of western Dolpo is described.

1. THE UNITS OF THE LOWER HIMALAYAS

The complicated geology of the Karnali region is shown by fig. 1 and we shall describe the traverse from Surkhet to the Jumla area starting in the S (fig. 1, section 2):

Surkhet is situated in the Siwalik Zone, the Miocene to Pleistocene molasse zone of the Himalayas. Grey sandstones regularly alternating with shales build up the foot of the Ranimatta Range.

Along the Main Boundary Thrust the Siwaliks are overridden by the Tansing Unit. Compared to the Kali Gandaki region, where this unit is very thick and extensive, it is rather reduced towards the W. The change is in the Sallyana area, where the Tansing Unit becomes confined to a narrow belt between the Main Boundary Thrust and the overthrust Chail Nappes (FUCHS and FRANK, 1970, Pl. 1, 2, 3 / sections 1, 2).

Krol Dolomite, a few meters thick only, forms the base of the unit. The Jurassic-Cretaceous Tal Formation follows with quartzites and quartzitic sandstones interbedded with shales (ca. 200 m) and grey green fissile shales (ca. 150—200 m). The latter might represent the Palaeocene-Eocene Subathus, however, this problem will be solved after the determination of the gastropoda und bivalves from a fossil horizon at the top of the named shales. Youngest beds of the Tansing Unit are the Dagshais (Lower Miocene), a 500 m alternation of thick-bedded grey sandstone and purple shale.

Thus in the sequence of the Tansing Unit all the formations older than Krol are missing here, the younger formations show normal stratigraphic succession.

The Tansing Unit, the lowest structural element of the Nepal Lower Himalayas appears to be of parautochthonous character. The unit may be followed from Nepal through the Krol Belt to Hazara in Pakistan and has been termed Parautochthonous Unit (FUCHS, 1971).

The Cail Nappe or Nappes, as there are subsidiary units in West Nepal und Kumaon*), are distinct allochthonous. Fossiliferous Tertiary beds exposed in a semi-window are evidence for thrust displacement of a least 90 km (FUCHS and FRANK, 1970, p. 80). Phyllitic metamorphism is characteristic of the rocks of the Chail Nappes, it increases towards the top.

Above the Dagshais — after a thrust — white to pink orthoquartzites (Nagthat) follow. In the Nagthats there are larger and smaller bodies of basic metavolcanic rocks like in Kumaon. The succeeding

*) Kumaon is Indian territory W of Nepal.

Chails consist of a monotonous thick series of greenish phyllites, sericite-chlorite schists, psammite schists, quartzites, and metadiabase.

As in Kumaon and the NW-Himalayas (Fuchs and Gupta, 1971; Fuchs, 1971) there are intrusive granites in the Chails. They have suffered the same phyllitic alteration as the Chails and have become metagranites or gneisses.

The thin metamorphic carbonate rocks N of Dailekh may indicate the boundary between subsidiary units of the Chail Nappes.

The Lower Crystalline Nappe overthrusts the Chails with typical Jutoghs, a series of phyllitic mica schists, garnet-mica schists, quartzites, and graphitic rocks (ca. 700 m). After 250—300 m of calc-mica schists and micaceous marbles Jutoghs follow again. Presence of garnet, phlogopite, biotite, and coarse muscovite in these rocks indicates higher metamorphic grade than shown by the Chail rocks.

The Upper Crystalline Nappe commences with augengneiss and predominating paragneisses, followed by carbonate gneiss, calc-mica schists, and marble. The succession of gneiss, quartzite, and carbonates seems to represent a stratigraphic sequence deformed in recumbent folds (ascent to the Mabu Pass). Kyanite is already found in the gneisses.

A subsidiary unit consisting of migmatitic gneisses and granitoids follows just S of the Mabu Pass. Filling the core of a large syncline these rocks have vast extension along the Tila- and lower Sinja Valleys.

In the upper course of the latter valley beneath the migmatites the lower units appear again. First the marbles, quartzites, and gneisses, then the Jutogh mica schists and quartzites, and calc-mica schists, and SW of Sinja the Chail Quartzites with bodies of amphibolite.

N of the depression filled by the Crystalline Nappes we enter a large culmination, where the Chail Nappes are exposed. Hagen (1959, 1969) found this window zone, though his boundaries of the windows, given also in Gansser (1964, Pl. 1) are not correct. Fuchs and Frank (1970) found a narrow continuation between the Jumla window and the Chail Nappes of the Hiunchuli area. The 1973 mappings showed that instead of two windows (Galwa and NW of Jumla) reported by Hagen there is one window of much larger extent.

The whole pile of nappes has become folded in that area due to strong compression after the thrust movements. Thus the culmination was brought about and later the Galwa Window was formed.

The Chail Nappe is continuous throughout the length of the Himalayas. Whereas it is exclusively formed by the Chail Formation in most of the areas, in Kumaon and W-Nepal it is built up by a stratigraphic sequence comparable to that of the Krol Belt (Auden, 1934). The succession Simla Slates — Chail — Nagthat — Blaini — Shali is best preserved in the Hiunchuli region and was described by Fuchs and Frank (1970). This is important as the existence of stratigraphic sequences makes it possible to decipher the complicated internal structure of the Galwa Window.

Fig. 1, section 2 shows that beneath the Chails and metagranites of unit C 3, unit C 2 appears consisting of the sequence Chail — Blaini. Next lower unit is C 1 formed by a thick pile of Shali Dolomite, dark argillites (Shali Slates), and the multicoloured Blainis. It is significant that, as in the Hiunchuli area, the grade of metamorphism increases from the lower to the upper units.

These three units are continuous with those of the Hiunchuli area (see also Fuchs and Frank, 1970, Pl. 1, 2).

The traverse along the deep Karnali gorge exhibits the structure of the western part of the window (fig. 1, section 1).

Beneath the Crystalline Nappes again we find thick Chails with smaller bodies of metagranite. But, towards ESE they join up with the Chails of unit C 2. In the same way the underlying carbonates join up with those of C 1. Unit C 1 shows a rather complete stratigraphic sequence from Simla Slates (?), Chail, Nagthat to a complex of Blaini, Shali Slates, and Shali Dolomite. Towards E the lower formations pinch out.

In the core of the anticlinorium another even lower structural unit appears consisting of Blainis and Shalis. We term it C 1 a. It seems that in the same region the highest nappe (C 3) pinches out. This is shown by our mappings, and mixing up of the units may be excluded. Thus, if we follow the Chail Nappe system to the W, a new lower unit comes in and the highest unit disappears. This indicates that the WNW-ESE striking deposition area of the Chail Nappes was cut by the nappe boundaries transversely in a NW-SE direction. This idea fits well with the way the subsidiary units develop in the Jangla Bhanjyang area (Fuchs, 1967; Fuchs and Frank, 1970, Pl. 1, 2, 3).

There is an interesting problem: Does the existence of stratigraphic sequences in W-Nepal and Kumaon just enable us to recognize subsidiary units in the Chail Nappe, or is it the cause of this special type of tectonics there? Certainly thousands of meters of quartzites and dolomites deposited on the Chails must have influenced the style of tectonics.

Comparison of fig. 1 of this paper with section 80 of Hagen (1959, Pl. 3; 1969) shows many differences. In same way I cannot follow the views of Ando and Ohta (in Hashimoto, 1973). All the named authors did not realize that the rock units of the Hiunchuli, Dailekh, and Galwa areas belong to the same nappe system. The Japanese geologists regard the rock series of the Galwa Window (their Jumla meta-sediment zone) as one stratigraphic succession, and thus neglect the tectonic repetitions.

There is no doubt that the rocks of the Galwa Window correspond with the Tejam Zone of Kumaon (Hagen, 1959, p. 14). Like Hagen we also assume an autochthonous to parautochthonous character but only for the lowest units (C 1 a, and eastern parts of C 1) of the Galwa Window (see also Fuchs and Frank, 1970, p. 84).

The epimetamorphic rocks of the Chail Nappes exposed in the Galwa Window are surrounded by the high grade metamorphic rocks of the overlying Crystalline Nappes. There is just one narrow connection ESE of Jumla, where the series of the Galwa Window join up with those of the Hiunchuli area (see FUCHS and FRANK, 1970, Pl. 1, 2).

The Crystallines N and E of the window represent the roots of the Crystalline Nappes. Our route from Jumla via Mugu to Dolpo crosses the root zone (Crystalline Central Zone, HEIM and GANSSER, 1939).

Whereas the Chail Nappes were altered under the conditions of the greenschists facies, the Lower Crystalline Nappe shows metamorphic grade of amphibolite facies. Retrogressive metamorphism is common. The rocks are garnetiferous phyllites and mica schists, two-mica paragneisses, quartzites, graphitic rocks, and amphibolites. Towards the top the mica schists contain garnet, kyanite, and staurolite. The occurrence of this mineral assemblage in the Lower Crystalline Nappe is an exception, as these minerals are typical of the Upper Crystalline Nappe. I explain this as a local increase of metamorphic grade in the Mugu Karnali region.

The Upper Crystalline Nappe commences with two-mica gneiss, quartzitic gneiss, quartzite, garnet-kyanite-mica schists, and -gneiss, amphibolite, and carbonate gneiss. This rock assemblage is followed by a complex of granite-gneiss, migmatites, paragneiss, and carbonate rocks, several thousand meters thick. Kyanite common in the lower part is replaced by sillimanite towards the top.

Towards the Tibetan border (Mugu region) rather homogeneous metagranites have intruded the Crystalline. This Mugu Granite (HAGEN, 1959, 1969) is continuous with the Mustang Granite of eastern Dolpo and the Thakkhola region. As shown by gneiss remains in these two-mica granites, the crystalline complex of the Upper Crystalline Nappe formed the base of the Tibetan Zone of Dolpo not only in the SW, but also in the NE. However, it was replaced there by the granites, which intruded in a later phase of the Alpine orogenesis.

The roof of the Mugu granite is formed by a succession of carbonate gneisses, marbles, calc schists and -phyllites. The series represents the basal parts of the Dhaulagiri Limestone. In these rocks the grade of metamorphism decreases towards the top.

The thickness of the Upper Crystalline Nappe may exceed 10.000 m and is great compared to the ca. 1000 m of the Lower Crystalline Nappe. The metamorphic grade of its rocks is higher than in the lower nappe and granitoids build up an essential part of the complex. Retrogressive alteration was observed only in the lowest part.

2. THE TIBETAN ZONE

Above the Central Crystalline we find a sedimentary zone built up by fossiliferous formations of the Palaeozoic and Mesozoic. The zone is known as the Tibetan or Tethys Zone. The fact that the metamorphism of the Crystalline decreases and dies away in the lower part of the sedimentary pile is observed throughout the length of the Himalayas from Kashmir in the NW to Bhutan in the E. Thus there is no sharp boundary between the Crystalline and the Tibetan Zone and they are tectonically inseparable.

The Tibetan Zone is represented in NW-Nepal by a large synclinorium („Tibetisches Randsynklinorium", T. Hagen, 1959). Its eastern parts were investigated by Dutch (Egeler et al., 1964), French geologists (Bordet et al., 1971), and Hagen (1968), and the central part (eastern Dolpo) by Fuchs (1967).

The western part of Dolpo was investigated by our 1973 expedition. The stratigraphic succession in western Dolpo is shown in fig. 2:

The Dhaulagiri Limestone an impure carbonate series of several thousand meters thickness forms the base. The formation consists of a rhythmic alternation of limestones, marls, argillites, calc-siltstones, calc-sandstones, and carbonate quartzites. There are also chloritic schists, which represent tuffaceous horizons. The great thickness, rhythmic character, and sedimentary structures indicate deposition under geosynclinal conditions (Fuchs, 1967; Fuchs and Frank, 1970). Crinoid stems, brachiopod shell beds, and flat gastropods were found, they give an Ordovician age. There are no fossil indications for Cambrian age, however, we left the possibility open, that lowest parts of the formation might be of that age. As the alteration has incorporated the basal parts of the formation into the Crystalline up to various levels, the lower boundary of the Dhaulagiri Limestone remains doubtful.

It is rather certain that our Dhaulagiri Limestone comprises the Garbyang and the Shiala Formations of Kumaon. From the descriptions of the lithology (Heim and Gansser, 1939; Valdiya and Gupta, 1972) it appears to me, that the monotonous series better would be taken together as one formation.

The Silurian is also somewhat doubtful in its boundaries. The dark graptolite bearing facies reported from the E by Egeler et al. (1964) and Bordet et al. (1971) is missing in western Dolpo. Our studies of several sections point to facies variations in that part of the stratigraphic column.

In certain sections there is a passage from the Dhaulagiri Limestone over dark blue limestones and dolomites with frequent marly and silty layers to the Devonian Dolomite. These passage beds are rich in crinoids and nautiloids of "orthoceras" type. The topmost part of the "Dhaulagiri Limestone" which has yielded "orthoceras" (Fuchs, 1967) lithologically resembles the Dhaulagiri Limestone, but belongs to these passage beds.

Grey, green, cream, purple, and pink flasery limestones, marls, and shales rich in crinoids and "orthoceras" replace the above described beds in other sections. No doubt this conspicuous series represents the Variegated Silurian (Heim and Gansser, 1939), for which Valdiya and Gupta (1972) were able to prove the Silurian age.

Apart from the fossils mentioned above we found poorly preserved bryozoa and a small brachiopod and gastropod fauna in the dark marls beneath the Devonian Dolomite.

The Silurian facies distribution from the SE to the NW — dark graptolite shales and limestones — dark limestones, marls, and dolomites with a local intercalation of silty shale — and the multicoloured limestones, marls, and shales with desiccation cracks — reflects shallowing of the basin towards W.

Similar facies relations are exhibited by the succeeding Devonian beds: From the SE towards the NW the flyschoid Tilicho Pass Formation is replaced by marls, limestones, and dolomites, and farther NW by a thick dolomite complex (FUCHS, 1967). In the landscape of western Dolpo these Devonian Dolomites are conspicuous as they form sharp escarpments, cliffs, and gorges. The series is well-bedded locally rather massive, and consists of light to dark grey dolomite, sandy dolomite, and carbonate quartzite. Oolites, intraformational breccias, desiccation cracks, ripple marks, and cross-bedding indicate shallow-water origin. Frequent algae and one coral colony excepted, the dolomites are devoid of fossils. In the S (Kanjiroba area), however, there is a 200 m zone of dark silty shales, siltstones, limestones, and dolomites, and brown and grey quartzites rich in algae, corals, brachiopods, gastropods, and crinoids. This fossil horizon, which is ca. 300 m below the top of the formation, is the same, from which the Middle Devonian fauna (FUCHS, 1967) was derived. The Devonian Dolomite is ca. 1000 m thick in the S, W, and NW, 400 to 700 m in the E.

The Muth Series of Kumaon shows a further increase in sand content and may be called Muth Quartzite (VALDIYA and GUPTA, 1972).

The named authors separated a carbonate-quartzite alternation from the Muth Series (HEIM and GANSSER, 1939) and termed it Kali Series. On the basis of their fossils they designated a Lower Carboniferous age to that series. Lithologically, however, the Kali Series clearly resembles to the Devonian carbonates and not to the Ice Lake Formation (Nepal), as cited by VALDIYA and GUPTA (1972, p. 15). Their Fenestella Shales are lithologically similar to the Lower Carboniferous Ice Lake Formation.

This formation pinches out towards NW (FUCHS, 1967) and is missing in the western part of the Dolpo Synclinorium.

After a gap comprising the Carboniferous and possibly also part of the Lower Permian, the Permian Thini Chu Formation overlies the Devonian Dolomite. The contact is conformable, but reworking of the dolomite, silicification along the old weathering surface, and burrows and fissures in the dolomite filled with sand from the overlying Permian quartzites indicate the gap in deposition.

The Thini Chu Formation consists of quartzites, conglomerates, calcareous sandstones, impure limestones, and dark silty shales. The rocks abound in fossils (corals, bryozoa, brachiopods, pelecypods, gastropods, trilobites, and crinoids). Plant remains and tetrapod foot prints show the litoral deposition of the formation (Fuchs, 1967). Thus the variation in lithology is easily understood. Therefore my coworker Prof. J. B. Waterhouse studied many sections in detail to establish the stratigraphy of the Permian and Scythian on fossil basis.

The thickness of the Thini Chu Formation is 30 to 60 m, which is less than in eastern Dolpo (see Fuchs, 1967; Egeler et al, 1964). In the NE of the mapped area the thickness increases to ca. 150 m.

It is interesting that the quartzites pinch out towards NE and are replaced by several hundred meters of shales and silty shales. The contact of these beds against the Devonian Dolomites was studied in the middle Panjang Khola: Above the dolomite there are ca. 15 m of reworked grey detrital dolomites und blue limestones containing fragments of dolomite (up to dm sizes). By alternation they pass into the succeeding shales. The bryozoa, brachiopoda, and crinoids in the basal beds indicate their Permian age.

In Kumaon the Kuling — or Productus Shales (Heim and Gansser, 1939) named Kringkrong Series by Valdiya and Gupta (1972) correspond with the Permian of Nepal. The series are less arenaceous in Kumaon.

The Lower Triassic, though 15 to 20 m thick only, is a marker horizon, composed of ligth grey, blue, and red thin-bedded limestone with shale intercalations. The Scythian forms a rigid light brown band between the dark brown weathering Permian and the soft formations of the Middle and Upper Triassic. Whereas red sediment colours are exceptional in the Scythian of eastern Dolpo, they are rather common in the NW. In the middle Panjang Khola, where red limestones and shales are most conspicuous, we found the exceptional thickness of almost 40 m.

The formation is rich in ammonites, and further yielded orthoconic nautiloids, brachiopods, and bivalves. Certain layers have the character of a condensed deposit.

A gap between the Scythian and the Permian is indicated by a thin lateritic layer and by reworking of the underlying dark shales in the basal 10 cm thick limestone bed of the Scythian. From fossil evidence it is rather certain that the uppermost Permian is missing according to personal communications of Prof. J. B. Waterhouse. The contact, however, was found conformable everywhere in Dolpo.

The Mukut Limestone consists of a thin-bedded alternation of dark blue limestones, marls, and shales like in eastern Dolpo. The pyritiferous beds bleach on weathered surfaces, therefore the formation is light coloured in the landscape.

The lowest 2—3 m of the Mukut Limestone are composed of nodular blue limestone, the nodules being mantled by dark and green-grey shale. This horizon, which is very rich in ammonites and brachiopods, morphologically forms the top of the Scythian band, but as shown by its fauna belongs already to the Anisian. This conspicuous horizon is not known from the eastern parts of Dolpo.

Ammonites, brachiopods, bivalves, and crinoids are frequent throughout the Mukut Limestone. But, due to the intricate folding of the thin-bedded formation, it is difficult to establish fossil horizons.

From the fossils FUCHS (1967) designated Anisian to Carnic age to the Mukut Limestone, and a correlation with the Kalapani Limestone of Kumaon is rather certain, though this limestone is less argillaceous.

The observation was made again that towards the N of Dolpo the lower part of the Mukut Limestone consists of soft dark shales. The basal nodular horizon, however, seems to be continuous throughout western Dolpo.

The Tarap Shales commence with a few meters of hard green, grey, brown weathering quartzite. Then dark shales and silty shales (ca. 200 m) follow. The soft beds contrast with the thick-bedded grey green siltstones and impure sandstones, which form the upper part (ca. 200 m) of the formation. In eastern Dolpo there is no similar subdivision of the Tarap Shales.

Graded bedding, flood casts, etc. stress the flyschoid character of the formation.

Fossils — ammonite fragments, brachiopods and bivalves — are very rare. FUCHS (1967) assumed Carnic-Noric age, which shall be tested by the new fossil finds. The Kuti Shales of Kumaon correspond to the Tarap Shales.

The thick-bedded Kioto Limestone (ca. 300 m), consisting of blue grey dolomite, limestone, sandy carbonates, white grey and brown carbonate quartzites, and green shale layers, forms rugged peaks and cliffs. The arenaceous beds predominate in the basal part — the so-called Quartzite Series — then the carbonates prevail.

Cross-bedding, oolites, and ripple marks indicate shallow-water deposition.

The fossils are algae, corals, bryozoans, brachiopods, bivalves, gastropods, and crinoids — ammonites are missing. This assemblage also points to a shallow-water environment.

The Kioto Limestone is continuous throughout the Tethys Zone. In age it ranges from the Rhaetic up into the Lower Dogger.

The Lumachelle Formation (Dogger) consists of alternating dark blue limestones and marls, black shales, and calcareous sandstones. There is a gradational contact between the thick-bedded Kioto Limestone and this thin-bedded series. Bivalves and brachiopods are very frequent and form shell beds, which gave the name to the formation (EGELER et al., 1964).

In north-western Dolpo the Lumachelle Formation is found in one occurence only, S of Sya Gompa (Fig. 3). In this squeezed syncline the formation is ca. 150 m thick.

A 50 m of the Upper Jurassic — lower Neocomian Spiti Shales occur in the same locality. The very thin-bedded black shales contain dark concretions. An ill-preserved belemnite was found.

Younger beds are unknown from Dolpo, probably they were removed by erosion. But the Cretaceous series were studied in the Thakkhola graben, where they are preserved (Egeler et al., 1964; Hagen, 1968; Bordet et al., 1971).

Thus the stratigraphic column is rather complete in the Tibetan Zone of northern Nepal. Caledonian disturbances have brought about the change from geosynclinal deposition of thick monotonous series to epicontinental sedimentation. Facies variations are particularly significant in the Silurian and Devonian: In the E geosynclinal conditions persisted, whereas in western Dolpo, Kumaon, Spiti, and parts of Kashmir epicontinental environments prevailed.

The gap in the Carboniferous and lowest Permian, is related with Hercynian disturbances. Non-deposition in the uppermost Permian may be related with latest movements of that orogeny.

The Tethys trough deepened in the Triassic. At the end of that period there is a pronounced shallowing throughout the Tibetan Zone.

There is a gap between the Middle and Upper Jurassic and the sedimentation ends in the Tethys after the Upper Aptien (Bordet et al., 1971).

Angular unconformities, however, have not been observed.

The structure of the Tibetan Zone of western Dolpo is not as complicated as that of the Lower Himalayas. The synclinorium was compressed from NE and SW. In the Thakkhola and eastern Dolpo the beds are folded in a harmonic style (Bordet et al., 1971; Fuchs, 1967, Pl. 8). The Devonian of western Dolpo is a rather rigid formation and thus influences the type of deformation (Fig. 3). Like a fractured bone the dolomites push into the soft Triassic formations along reversed faults and small scale thrusts. These imbrications, however, disappear in the mobile Triassic rocks, they reacted by folding. The directions of the movements vary, only in the Kanjiroba Himal NE-vergency predominates.

There are two main synclines in north-western Dolpo. The one S of Sya Gompa is the continuation of the Charka-Tarap Syncline (Fuchs, 1967). The syncline ends ca. 15 km WNW of Sya Gompa.

The Popa Syncline joins up with the Koma Syncline (Fuchs, 1967). It is this syncline which continues farthest to the NW. E of the Langu-Mugu Valley junction this syncline and the Dolpo Synclinorium end.

Thus the folds of the Dolpo Synclinorium do not swing around into a N—S direction, as indicated in Gansser's map (1964, Pl. 1 A). Their WNW—ESE strike persists, but the large updoming, which has led to the formation of the Galwa Window, makes the SW-margin of the synclinorium swing around into a N—S direction. Thus the folds of the Tibetan Zone strike into the air towards WNW. W of the Galwa Window in the Saipal the Tibetan Zone begins again and continues into Kumaon.

REVIEW

Our recent investigations prove my view that the stratigraphic and structural units are continuous throughout the length of the Himalayas. Certainly regional peculiarities and individual features do exist, but the main geological units continue across political or geographic boundaries. Thus there is no principal difference between the geology of the Punjab-, Kumaon-, or Nepal Himalayas. Nowadays there are lots of geologists working in the Himalayas, and they establish their own stratigraphy and tectonics within their small areas of investigation. Thus a flood of new stratigraphic and tectonic names has been created, and as in the times of the construction of the tower of Babel understanding between the worker gets lost, even if they belong to the same working group (eg. HASHIMOTO, 1973). Therefore it should be the target to find a common base again as in the days of AUDEN, WEST, and WADIA.

ACKNOWLEDGEMENT

The Austrian Geological Himalayan Expedition 1973 was sponsored by the following institutions: „Fonds zur Förderung der wissenschaftlichen Forschung", „Bundesministerium für Wissenschaft und Forschung", „Kulturamt der Stadt Wien", „Österreichische Akademie der Wissenschaften", „Österreichischer Alpenverein", and „Rohöl-Aufsuchungs GmbH".

Their aid has made our research possible, for which I am highly indebted.

To Hofrat Dr. A. RUTTNER, former head of the Austrian Geological Survey, I am very grateful for having given me leave for my Himalayan studies.

References

AUDEN, J. B., 1934: The Geology of the Krol Belt. Rec. G. S. I, 67 (4), 357—454, Calcutta.

BORDET, P., M. COLCHEN, D. KRUMMENACHER, P. LEFORT, R. MOUTERDE and M. REMY, 1971: Recherches géologiques dans l'Himalaya du Népal, région de la Thakkhola. Edit. Centr. Nat. Rech. Sci., 1—279, Paris.

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

FUCHS, G., 1967: Zum Bau des Himalaya. — Österr. Akad. Wiss., math. nat. Kl., Denkschr. 113, 1—211, Wien.

FUCHS, G., 1971: Die Geologie des Himalaja und ihre Probleme. Jb. d. Ö. A. V. 1971, 197—210, Innsbruck.

FUCHS, G., and W. FRANK, 1970: The Geology of West Nepal between the rivers Kali Gandaki and Thulo Bheri. — Jb. G. BA., Sdbd. 18, 1—103, Wien.

FUCHS, G., and V. J. GUPTA, 1971: Palaeozoic Stratigraphy of Kashmir, Kishtwar and Chamba (Panjab Himalayas). — Verh. G. BA., 1971, 1, 68—97, Wien.

GANSSER, A., 1964: Geology of the Himalayas. — Interscience Publishers John Wiley and Sons Ltd., London—New York—Sidney, 1—289.

HAGEN, T., 1959: Über den geologischen Bau des Nepal-Himalaja. — Jb. St. Gall. Nat. wiss. Ges., Bd. 76, 1—48, St. Gallen.

HAGEN, T., 1968: Report on the Geological Survey of Nepal. Vol. 2: Geology of the Thakkhola. — Denkschr. Schweiz. Naturf. Ges., 86/2, 1—160, Zürich.

HAGEN, T., 1969: Report on the Geological Survey of Nepal. Vol. 1: Preliminary Reconnaissance. — Denkschr. Schweiz. Naturf. Ges., 86/1, 1—185, Zürich.

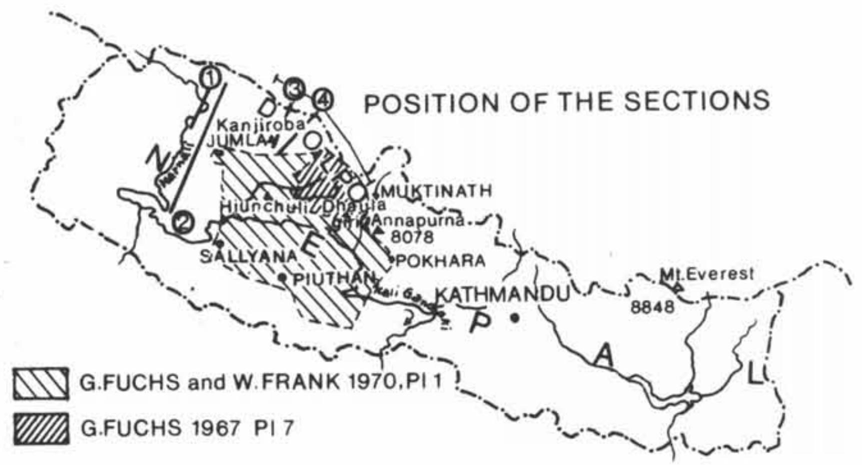
HASHIMOTO, S., 1973: Geology of the Nepal Himalayas. — Himalayan Commitee of Hokkaido University, Sapporo, 1—286.

HEIM, A., and A. GANSSER, 1939: Central Himalaya, geological observations of the Swiss expedition 1936. — Mem. Soc. Helv. Sci. nat., 73 (1), 1—245, Zürich.

VALDIYA, K. S., and V. J. GUPTA, 1972: A Contribution to the Geology of Northeastern Kumaon, with special reference to the Hercynian Gap in Tethys Himalaya. — Himalayan Geology, 2, 1—33, Delhi.

Bei der Schriftleitung eingelangt am 26. Februar 1974.

Sections through the Karnali Region, W-Nepal, G.FUCHS, 1974

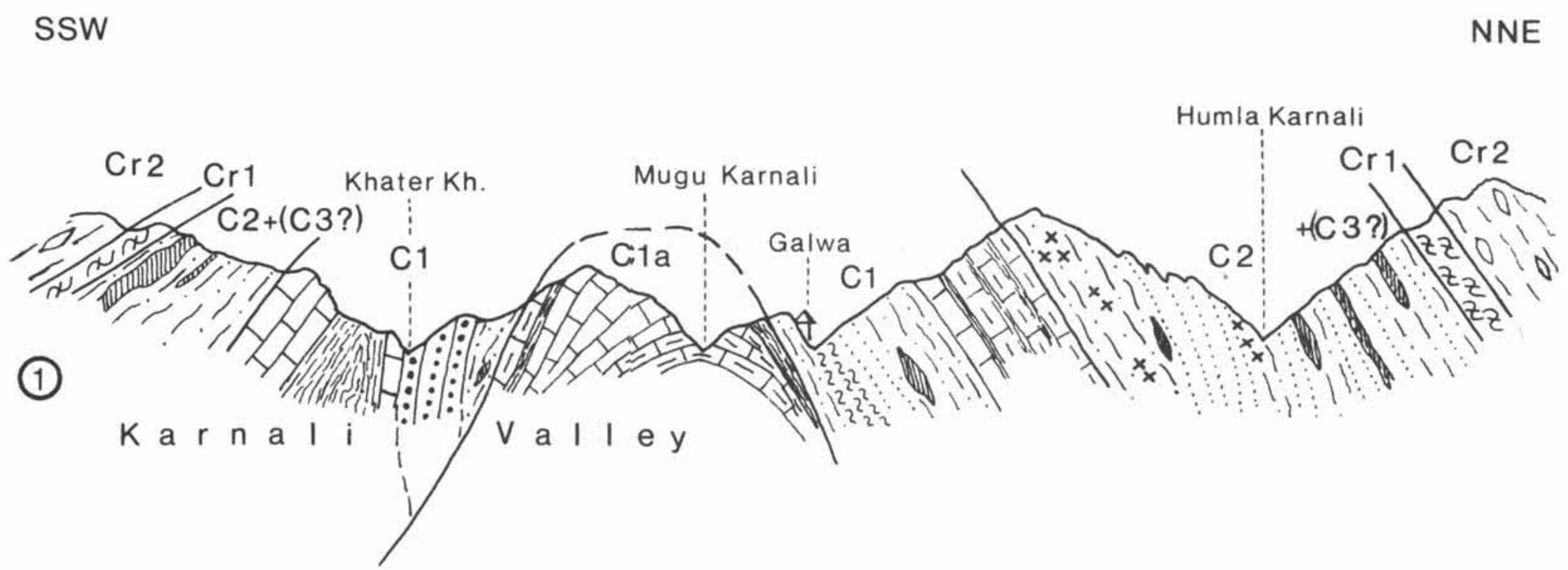


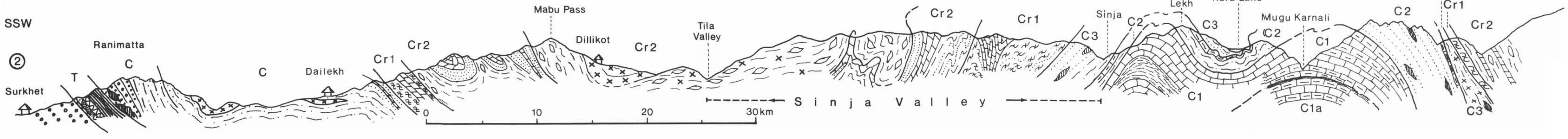
I N D E X :

- Siwaliks (Miocene-Pleistocene)
- Dagshai (L.Mioc.)
- Tal, shaley, quartzitic
- Krol, Shali Dolomite
- Blaini
- Infra Krol, Shali Sl.
- Nagthat
- Basic metavolcanic rocks
- Chail, quartzites and shales, quartzites
- Simla Slates
- Metagranite
- Jutoghs (Lower Crystalline Nappe)
- Metamorphic carbonate rocks
- Quartzites in Crystalline
- Gneiss in gen., augengneiss

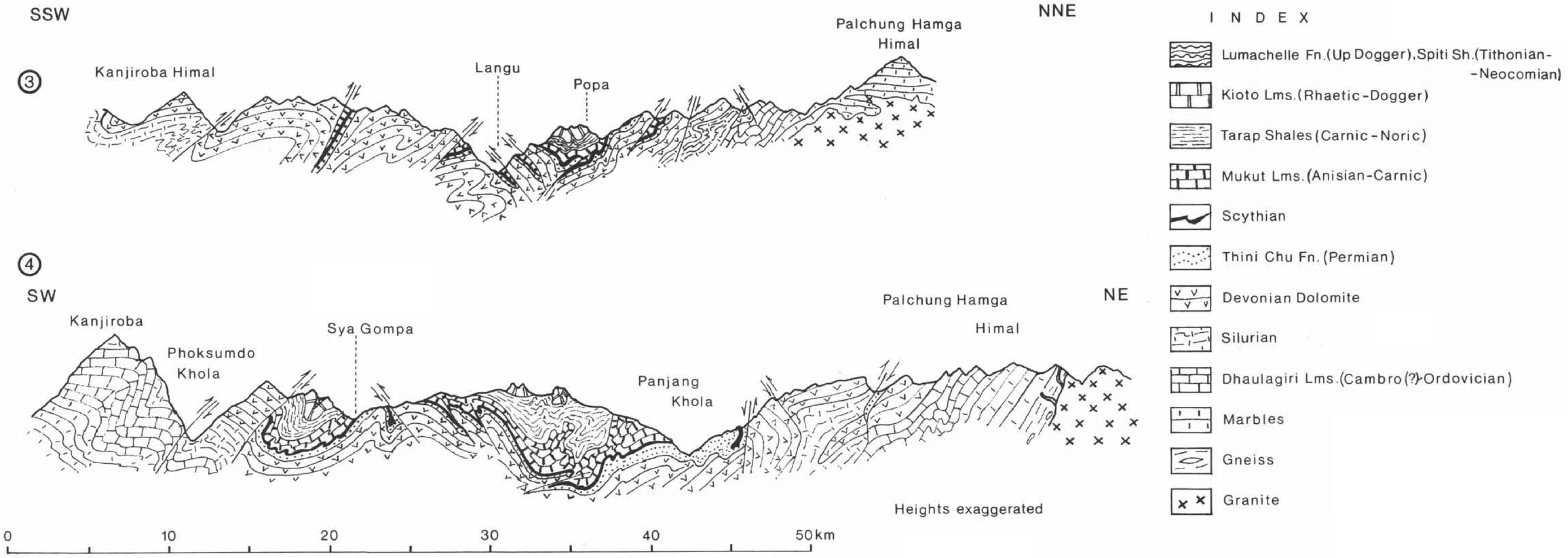
T = Tansing Unit
C(1,1a,2,3) = Chail Nappes
Cr(1,2) = Crystalline —"—

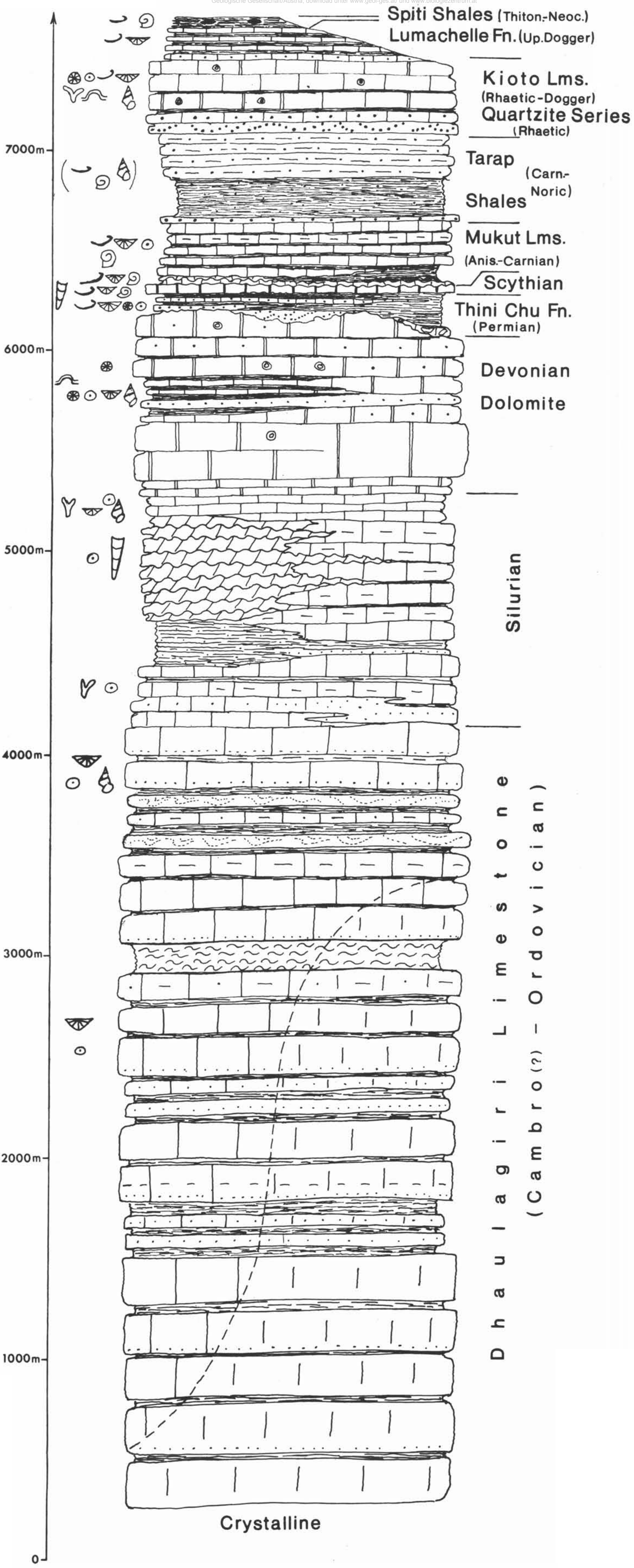
Heights exaggerated





SECTIONS THROUGH WESTERN DOLPO G. FUCHS, 1974





Stratigraphic Column of Western Dolpo

G. FUCHS, 1974

INDEX:

- quartzites, sandstones
- siltstones
- argillites, silty shales
- tuffites
- limestones
- dolomites
- marly, sandy carbonates
- oolitic
- metamorphic limestones
- flasery limestone and marls
- conglomeratic limestones

- algae
- bryozoa
- crinoids
- corals
- bivalves
- gastropoda
- orthoconic nautiloids
- ammonites
- brachiopoda