©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

Jahrb. Geol. B.-A.	Band 121, Heft 2	S. 219—241	Wien, Dezember 1978

The Tectonics of the Garhwal—Kumaun Lesser Himalaya

By GERHARD FUCHS *) and ANSHU K. SINHA **)

With 3 plates (= Beilagen 5—7)

Schlüsselwörter
Tectonics
Garhwal
Kumaun
Lesser Himalaya

CONTENTS

Abstract 219
Zusammenfassung 219
1. Introduction 220
2. Some remarks to Stratigraphy 220
3. The Parautochthonous Unit 221
4. The Chail Nappes 228
5. The Crystalline Nappes 235
6. Conclusions 236
Acknowledgement 237
References 237

Abstract

The paper is an attemt to give an uniform picture of the structure of Garhwal — Kumaun Lesser Himalaya. In combining data from literature with own observations the experiences from Western Nepal were invaluable aid.

The lowest structural unit north of the Main Boundary Thrust is the Parautochthonous Unit comprising the Krol Belt. The existence of a "Krol Nappe" derived from afar is denied. The above unit is succeeded by the Chail Nappes. The lower two subsidiary units consist of Chail-Deoban sequence, the uppermost nappe is built entirely by the Chail Formation and oversteps the lower units and the Parautochthonous Unit in unconformable way. The Crystalline Nappes are represented by a lower unit of medium grade metamorphics and an upper unit composed by the high grade crystalline. The paper, however, concentrates on the description of the Parautochthonous Unit and the Chail Nappes, which provide the main structural problems.

Zusammenfassung

Die Arbeit trachtet, ein einheitliches tektonisches Bild vom Niederen Himalaya im Bereiche von Garhwal — Kumaun zu geben. Beim Verbinden von Literaturdaten mit eigenen Beobachtungen waren die Erfahrungen aus West-Nepal überaus wertvoll.

Address of the authors: *) Dr. G. FUCHS, Geologische B-A. Wien, A-1031, P.O.B. 154.
**) Dr. A. K. SINHA, Wadia Institute of Himalayan Geology, 15 Municipal Rd., Dehra Dun 248001, India.

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

Die tiefste Struktureinheit nördlich der Main Boundary Thrust ist die Parautochthone Einheit, die im wesentlichen die Krol-Zone umfaßt. Die Existenz einer durch Fernüberschiebung herangebrachten „Krol-Decke" wird abgelehnt. Über der Parautochthonen Einheit folgen die Chail-Decken. Die beiden tieferen Teildecken werden von der Schichtfolge Chail bis Deoben aufgebaut, während die höchste Teildecke ausschließlich aus Chail-Formation besteht. Diese Teildecke überlappt die beiden tieferen und die Parautochthone Einheit in diskordanter Weise. Die Kristallin-Decken sind vertreten durch eine tiefere Einheit, bestehend aus mittelgradigen Metamorphiten, und einer höheren, aufgebaut von hochmetamorphem Kristallin. Die Arbeit konzentriert sich aber auf die Beschreibung der Parautochthonen Einheit und der Chail-Decken, welche die tektonischen Hauptprobleme liefern.

1. Introduction

The knowledge of the stratigraphy and tectonics of the classical areas in the Indian Himalaya is the key for deciphering the geology of Nepal. On the reverse the observations made in Nepal are invaluable aid for the understanding of the Indian part of the Himalaya. Particularly Kumaun and Garhwal reveal a structural pattern very close to Western Nepal. This is evident from the classical work done by AUDEN (1937) or HEIM & GANSSER (1939) and is becoming even clearer by the recent work of the Indian geologists. Unfortunately almost every worker creates his own terminology, which is only applied for a comparatively small area. The multitude of names has led to a series of wrong correlations and consequently gave rise to a non-uniform structural picture of Kumaun-Garhwal. However, from the descriptions the great similarity to Western Nepal is obvious. The "Structural set-up of the Kumaun Lesser Himalaya" presented by VALDIYA (1976)shows inconsistency in several points. This led the authors with impulse to collect the geological data published in a series of papers and to interpret the observations with FUCHS' experience from Nepal. Several excursions helped in the development of the concept presented in this paper. In areas not visited some problems had to be left open. Inspite of many handicaps the attemt ist made to outline the tectonics and to give an uniform structural picture of Garhwal and Kumaun.

2. Some remarks to Stratigraphy

Work in various parts of the Himalaya showed that the stratigraphical concept of PILGRIM & WEST (1928) and AUDEN (1934) may be applied in all the Lesser Himalaya from Pakistan to Nepal (FUCHS 1967, 1974, 1975, 1976; FUCHS & FRANK, 1970; FUCHS & SINHA, 1974). Further the inner and outer zones of the Lesser Himalaya were correlated as in table 1 (FUCHS' view):

Outer Zone	Inner Zone
Dagshai	Dagshai
Subathu	Subathu
Tal	Tal
Krol	Shali-Deoban
Infra Krol	Shali Slates
Blaini (Mandhali)	Blaini (Mandhali)

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

Nagthat Chandpur	Jaunsar	Nagthat Chail
Simla Slates		Simla Slates

When this correlation was established FUCHS took it as granted that Blaini was Upper Palaeozoic and the Simla Slate — Krol succession was mainly Palaeozoic. Since then much dispute arose about the age of the Lesser Himalayan formations. Arguments were advanced for Precambrian (e. g. SINHA 1975 b) respectively Palaeozoic age and there are advocates for both theories. Most workers hold the conservative view of an Upper Palaeozoic — Mesozoic age of the Blaini — Krol sequence, but regard the Shali — Deoban Precambrian. Considering the present situation we must say that the age problem is unsolved. FUCHS (1975) finds that the arguments are more in favour of a Palaeozoic age of the Lesser Himalayan sequence. One thing, however, is definite to FUCHS thinking that Chandpur and Chail respectively Krol and Shali are to be correlated.

Though this is a paper on tectonics and regional geology so the above mentioned remarks on the stratigraphy were necessary. Conspicuous mylonite zones are generally absent. By regional mapping and correlative studies in different regions it becomes clear, what are stratigraphic successions and where are the tectonic breaks. In this way a stratigraphical concept is formed, which in further work determines an author where to place structural lines and nappe boundaries.

3. The Parautochthonous Unit

AUDEN described the geology of the Krol Belt in his classical paper (1934). This zone may be taken as a type area for the Parautochthonous Unit. FUCHS (1967) used the term "Krol Unit" to describe the corresponding structural unit in Nepal. However, in a later paper FUCHS & FRANK (1970) gave the local name Tansing Unit. Further work, particularly in the North-Western Himalaya, proved that the named structural unit forms a characteristic element from Pakistan in the west to the NEFA (Arunachal) Himalaya in the east. The material building up that zone may change, thus the Krol Limestone is replaced by Shali Dolomite in Hazara (Sirban) or by Baxas or Damuda rocks in the eastern Himalaya. The structural characteristics, however, are very constant. The unit, composed mainly of pre-Tertiary rocks, overrides the Tertiary Zone along a continuous thrust (Main Boundary Thrust). The Parautochthonous Unit shows a series of anticlines and synclines, the first frequently sheared by reversed faults. Thus combined fold and wedge structures are characteristic. There is a marked contrast between the often steeply dipping beds which build up that unit and the overlying nappes being horizontal or gently dipping. This contrast in tectonic style and the fact that only the southern frontal portions are proved by windows to be allochthonous shows that this belt is best termed parautochthonous. Therefore FUCHS (1975) introduced the term Parautochthonous Unit for this non- or only slightly metamorphosed rock belt between the Tertiary Zone in the south and the nappes overriding from the north. This unit comprises the Islamabad- and Abbottabad Zones of Hazara, the Autochthonous Fold Belt (WADIA, 1931), the Krol Belt,

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

the Tansing Unit of western Nepal, and the Baxa-Damuda Belt of the eastern Himalaya (SINHA treats Krol outer belt and inner Shali belt as two separate units).

In the S i m l a region the Krol Belt shows SW-directed folds (AUDEN, 1934; BHARGAVA, 1972; SINHA, 1972, 1974). The Padhmunda and the Krol Synclines are separated by an anticline at Solon; Simla Slates and Subathus in the core of that anticline, according to AUDEN (1934), represent a tectonic window. The rocks exposed in that window seem to belong to northern portions of the Tertiary Zone. The displacement of the southern parts of the Krol Belt proved by that window, however, is only 3 km. The structural plane separating the Tertiaries from the rock series of the Krol Belt was called the "Krol Thrust" by AUDEN (1934), who assumed the existence of a "Krol Nappe". In view of FUCHS (1967), RANGA RAO (1968), and RUPKE (1974), the Krol Thrust is just the Main Boundary Thrust, which elsewhere separates the Tertiary Zone from the older rock series of the Lesser Himalaya. The above mentioned authors doubt the allochthonous nature of the Krol Belt (see also SAKLANI, 1970; S. P. SHARMA & N. S. VIRDI, 1976 etc.).

Towards SE the two synclines mentioned above join to form one big synform built mainly by Infra Krol and Krol rocks (Sain Dhar Syncline of Outer Krol Belt, BHARGAVA, 1972). At Dadahu the syncline becomes narrow and ends at Sataun.

Along the Giri Thrust the rocks of the Krol Belt come in contact with the Simla Slates of the Simla Slate Thrust Sheet, a higher tectonic unit in view of FUCHS. Probably the Giri Thrust does not represent the basal thrust plane of the Simla Slate Thrust Sheet but is rather a younger reverse fault (comp. BERTHELSEN, 1967). Certainly the Giri Thrust does not join up with the Krol Thrust making the Krol Belt a superficial nappe in the sense of SRIKANTIA & BHARGAVA (1974). Under its influence the northern limb of the Krol Syncline is much sheared and overturned in the Kandaghat area (AUDEN, 1934). In the region of the lower Ashmi- and Giri Rivers Simla Slates of the Parautochthonous Unit (Krol Belt) and of the Simla Slate Thrust Sheet come in touch along the Giri Thrust. Therefore some workers doubt that the Simla Slates on both sides of the Giri Thrust belong to different tectonic units (FRANK personal communication; SINHA, 1977, regards the Simla flyschoid rocks as parautochthonous, deposited originally in a flysch graben of Upper Riphean and younger age). Towards SE also Blainis and Jaunsars of the Simla Slate Thrust Sheet and even the Chail Nappe come in touch with the Krol Belt along the Giri Thrust. Further SE along the lower course of the Giri River the Giri Thrust cuts through the Krol Belt. There it shears the anticline consisting of Jaunsars, which separates the Sain Dhar Syncline of the Outer Krol Belt (BHARGAVA, 1972) from the Inner Krol Belt (Korgai- and Nigali Dhar Synclines).

The latter synclines, which rather form a syncline doubled by a minor anticline, comprise all formations from the Jaunsars up to Upper Tal. The southern limb of this wide synform is disturbed by the Giri Thrust respectively by shearing planes parallel to the latter. The northern limb is overridden by the Chail Nappe, apparantly in an unconformable way. The appearance of the Nigali Dhar Syn-

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

cline indicates the widening of the Parautochthonous Unit in Garhwal. There the higher nappes retreat to the north, which protruded far to the SW in the Chor region.

Here we come across the most crucial point of the Lesser Himalaya, rather rich in unsolved problems. The Nagthats and the underlying Chandpurs west of the Tons River are definitely belonging to the Nigali Dhar Syncline, that means to the Krol Belt. They come in contact with the rocks of the Chail Nappe forming the basal portions of the Chor outlier. These rocks are very similar to the Nagthats and Chandpurs of the Krol Belt and in case of the Chandpurs are even identical in age. This is probably the reason why in his map RUPKE (1974) shows the Nagthats continuous to the north following the Chails and surrounding the Tons culmination. Similar interpretations are given by SRIKANTIA & BHARGAVA (1974, Fig. 1) and VALDIYA (1976, Fig. 2). The existence of a "Krol Nappe" (AUDEN), which overlies the deeper Deobans along the "Tons Thrust" is the consequence. On the contrary we are convinced that the semi-metamorphic Deobans and associated clastic formations are structurally higher than the less altered series of the Krol Belt. From their lithology, tectonic style, and particularly if followed SE, there is no doubt that they represent lower subsidiary units of the Chail Nappe system (in view of FUCHS), which overthrust the Parautochthonous Unit (Krol Belt) (Pl. 1, 2). Neither in Simla nor elsewhere there is a trace of the roots of the "Krol Nappe" at the base of the Chail Nappe or the Central Crystalline and the advocates of the Krol Nappe hypothesis merely can refer to the quartzite complexes in association with the Chails at the base of the Crystalline. These quartzites, however, are part of the Chails and in view of FUCHS have nothing to do with the Krol Belt.

There is not much doubt that the Nigali Dhar and Korgai Synclines continue in the Mussoorie Syncline. The younger formations are eroded in the Tons-Yamuna depression and there the synform consists mainly of Chandpurs. In the southern limb these Chandpurs overthrust a series of narrow bands consisting of carbonate respectively clastic formations (AUDEN, 1934, M. P. SINGH, 1975). From SINGH's descriptions it appears that there are at least two scales built up by Nagthats (Nagthats, Bhadraj, and Kalsi Slates and Quartzite), Blainis (Kalsi-Naraya Limestone, Boulder bed) and carbonates possibly corresponding to Krol (Dhaira Limestone). In our view these scales are remnants of the Sain Dhar Syncline, which towards SE becomes reduced and finally pinches out between the Giri and Main Boundary Thrusts. Though from AUDEN's and SINGH's work it is very suggestive to connect the above beds with resembling formations in the northern limb of the synform, we are somewhat doubtful about that. In the Yamuna section (Pl. 1, 2) the Chandpurs pass down into Simla Slates (Damta Formation, RUPKE, 1974) north of the Bhadri Gad junction near the village Marora. At Naingaon a band (150—200 m) of dark grey limestone crosses the valley. This band was mapped as Mandhali by PACHAURI (1972) who assumed the "Tons Thrust" forming the boundary between the carbonates and the underlying Morar-Chakrata rocks (= Simla Slates). The limestones, however, are intimately connected by alternation with the surrounding flyschoid slates. These rocks resemble very much to the Naldera and Kakarhatti Limestones respectively

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

to carbonates in the upper portion of the Simla Slates of Nepal. All the rocks are in stratigraphic continuation and there is no indication of the "Tons Thrust". The southern dip of the strongly folded Simla Slates changes to north around the village Damta, and north of the Sauri Gad there is again a passage into overlying Chandpurs. These consist of slates and siltstones much less laminated than the Simla Slates and associated with metadiorite (SINHA & BAGDASARIAN, 1976). RUPKE (1974) termed this series Sauri Gad Formation, PACHAURI (1972) spoke of the Kunnan Unit. In the north the Chandpurs are overthrust by Deoban limestones and dolomites. In our view the section along the Yamuna up to the base of the Deoban is in normal stratigraphic order. Going north from the core of the Mussoorie Syncline to the core of the Damta Anticline one crosses the complete sequence of the Krol Belt from the Tal down to the Simla Slates. The Chandpurs north of the Sauri Gad represent the northern limb of the Damta Anticline truncated by the lowest Chail Thrust (FUCHS). (SINHA regards it to be the tectonic contact dividing the Deoban carbonate zone and flyschoid Morar-Chakrata (= Damta) structural facial zone.) From the Main Boundary Thrust up to here we find one stratigraphic sequence folded in a syncline (Mussoorie) and an anticline (Damta). Therefore there is no need to assume a "Tons Thrust". All series belong to the Parautochthonous Unit. Difficulties for that explanation arise, if we consider the region west of the Yamuna towards the Tons. We were not able to visit that area, but according to AUDEN (1934, 1937), BHARGAVA (1972), M. P. SINGH (1975) and others bands of younger formations occur between the overlying Chandpur and the main mass of the Simla Slates of Chakrata. Besides the Bansa Limestone, which seems to be a stratigraphic intercalation, there are Nagthat and Blaini type rocks (Mandhali) and even nummulitic beds are reported in connection with the Simla Slates.

AUDEN (1934) mentiones several occurrences of nummulitic beds and Dagshais below his "Tons Thrust", but without recording of fossils. Thus the determination of these beds seems to be based on lithology. On p. 440 AUDEN himself notes that Dagshai-like sandstones occur as boulders in the Blaini, proving that there are such rocks of pre-Mesozoic age. AUDEN therefore assumes two sandstone series of quite different age, but we doubt whether there are any Tertiary beds in that zone. However, we admit that the occurrence of Blainis, Nagthats etc. indicates disturbance of the zone in dispute. For this discussion it is of interest that K. K. DUTTA & G. KUMAR (1964) in their map designate the whole series between the Simla Slates in the north and the Chandpurs in the south as Mandhali. Further they do not show a band of Tertiaries along the "Tons Thrust" as does SINGH (1975). We think that the stratigraphic sequence is complicated there by a scale structure with south-dipping shear planes rather than of a nappe boundary. It is a fact that the Deoban Limestone overlies Chandpurs and Simla Slates in the east (Yamuna) and the reverse is reported from west of Chakrata (see RUPKE, 1974, map). Pl. 3 of the present paper shows a detailed section through the Deoban — Chakrata area observed by A. K. SINHA. Simla Slates and Deobans border each other along a steep tectonic contact. Farther away from that zone of disturbance both formations predominately dip to the north.

Treating the "Tons Thrust" AUDEN (1934, p. 439) notes that in the Tons

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

Valley "Jaunsar rocks occur in the 6.000-foot scarp on the right bank, dipping south-west, while on the left bank occurs the Deoban limestone, dipping apparently to the north-east in cliffs and terraces nearly 7.000 feet in height. A great dislocation is therefore required to explain the juxtaposition of unlike rocks on the two sides of the Tons river". JAIN (1971, Fig. 6), BHARGAVA (1972, Fig. 8, section 6) as well as VALDIYA (1976, Fig. 3, section C) show divergent dip on both sides of their "Tons Thrust". Similar unconformable relations are also frequently observed along the thrust contacts in Nepal (FUCHS & FRANK, 1970, Pl. 3,sections 2—8, 19, 20). In such cases it can only be decided which unit is higher by considering the regional situation, that means the areal extent and continuation of the rock series. The decision which rock series belong to which structural units and which is the higher, depends largely on the stratigraphic concept and on personal experiences of diverse authors. From the knowledge of the geology of Western Nepal (FUCHS & FRANK, 1970; FUCHS, 1974, 1977) the Deobans and associated quartzite-phyllite formations represent lower subsidiary units of the Chail Nappe system and overthrust the Jaunsars and Simla Slates south of them. Their higher grade of alteration as well as their regional extent (see Pl. 1) fit well with that concept. There is no indication that the series south of the Deobans of the Chakrata area continue to the north of the Sainj River and overlie the Deobans. K. C. PRASHRA (1976), however, traced a thrust plane ("Tons Thrust"), marked by discontinuous bodies of Simla Slates and Eocene beds, around the Deoban culmination. According to PRASHRA the named rocks overlie stratigraphically the Deoban Limestone and are overlain by Mandhalis along the "Tons Thrust". In an earlier paper (K. C. PRASHRA, P. C. KHANNA, and R. N. SRIVASTAVA, 1975) the above Mandhalis were taken as highest member of the Deoban Formation, the Simla Slate-Tertiary zones as clastic (stratigraphic) intercalation in the Deoban. From PRASHRA's description it appears that he actually traced a tectonic horizon, along which not only Simla Slates and Subathus, but also Chail phyllites and quartzites, Mandhali-Blaini rocks, as well as Shali Slates are found in tectonic mixture. FUCHS supposes that these rocks together with the overlying carbonates represent Chail Nappe 2, which overthrusts the Deoban of Chail Nappe 1 and are themselves succeeded by a thick sequence of Chails of Chail Nappe 3 (see chapter 4). That means that the tectonic horizon found by PRASHRA is a structural plane between the Chail Nappes and does not represent a continuation of a "Tons Thrust".

If we follow the Parautochthonous Unit towards the east, JAIN's papers (1971, 1972) give valuable informations. The most important structural element is the Mussoorie Syncline, which comprises the sequence from Chandpur to Tal. In its axial region outliers of higher nappes were found by AUDEN (1937, "Garhwal Nappe") which shall be dealt with in the chapter on the Chail Nappes. The southern limb of the Mussoorie Syncline overrides the Siwalik Zone along the Main Boundary Thrust. Approximately 5—6 km NE of that thrust, like in Solon, windows are exposed consisting of Simla Slates and Subathus. These Bidhalna- and Pharat Windows found by AUDEN (1937) were recently studied by JAIN (1972). The frame of the windows is formed by the Chandpurs of the Mussoorie Syncline. The windows prove an allochthonous nature of the southern limb of

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

this Syncline, which does not mean that they are proof of a "Krol Nappe". The fact that the southern portions are allochthonous is expressed in the name Parautochthonous Unit.

The extended Nagthat, Chandpur, and Simla Slates of the northern limb of the Mussoorie Syncline and of the Damta Anticline observed in the Yamuna Valley become reduced towards the east. The Damta Anticline pinches out, a last remnant consisting of Simla Slates seems to be represented by JAIN's Lahiri A Member (1971). The Lahiri B and C Members (and JAIN's Chandpur) are the eastern continuations of the Chandpurs respectively Nagthats of the Yamuna section (compare Pl. 1 with JAIN's Fig. 1). These rocks build up a minor syncline (Deosari Syncline) in the rock series forming the northern limb of the Mussoorie Syncline north of the Agar Fault. Contrary to JAIN we see these formations in normal stratigraphic order and do not assume any thrust in between them. Along the Nagon Valley, however, a significant thrust cuts the named formations. The SW dip of the Simla Slate—Nagthat sequence (JAIN's Lahiri to Nagthat) contrasts to the prevailing NE dip of JAIN's Dharasu Formation, therefore this author spoke of the Nagon Anticline. JAIN assumes that along the „Tons Thrust" his Lahiri overrides the Dharasu Formation, which forms the anticline. JAIN's Dharasu Thrust Sheet, however, represents Chail Nappe 3, which overthrusts the lower Chail Nappes (1, 2) characterized by Deoban Limestone in the Yamuna section. Along the Nagon Valley Chail Nappe 3 is in unconformable contact with the lower formations, towards SE it comes in touch even with the Krol Limestone of the Mussoorie Syncline. Thus Chail Nappe 3 overlaps a series of lower structural units (see Pl. 1, 2). This unconformable relation is also evident from the way Chail Nappe 3 oversteps successively the formations of the northern limb of the Mussoorie Syncline. The discordant and very complicated thrust contact of Chail Nappe 3 and the Krol is observed along the Chamba — Narendranagar motor road NE of the village Nagani. (The division into units C 1, C 2 etc. is according to the concept of FUCHS.)

In the valley of the Hiunil River the Mussoorie Syncline has its south-eastern end. But south of the anticlinal structure indicated by the Bidhalna—Pharat Windows a new syncline starts in the Ganges Valley. This Garhwal Syncline was studied particularly by MIDDLEMISS (1887 a, b, 1888, 1890), AUDEN (1937) and recently by T. M. GANESAN (1972), RAVI SHANKER & T. M. GANESAN (1973) and others. The Garhwal Syncline may be correlated with the Sain Dhar Syncline, such as is the Mussoorie Syncline with the Korgai- and Nigali Dhar Synclines of the Krol Belt. The Parautochthonous Unit is built by a sequence comprising the succession from Chandpur up to Subathu. In the south-western frontal parts the older formations are reduced or missing at all, whereas in the northern limb there is a thick development of Nagthat ("Saknidhar Formation", KUMAR et al, 1974). It should be emphasized that there is no indication for an "Autochthonous Window" in the Nayar Valley (FUCHS, 1967, p. 147). Following AUDEN, VALDIYA (1976, Fig. 2) still assumes the existence of a huge window. Along the so-called Garhwal Thrust the Parautochthonous Unit is overthrust by a thick pile of metamorphosed rocks filling the central portions of the Garhwal Syncline. Between these Chail Nappes and the Parautochthonous Unit or representing a lower

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

subsidiary unit of the first, there is an intercalated unit — the Lower Bijni Unit (SHANKER & GANESAN, 1973) containing fossiliferous Permo-Carboniferous beds (GANESAN, 1972). This fossil find in series of definitely Lesser Himalayan origin is of much importance for the stratigraphical and palaeogeographical problems of that part of Himalaya. This topic, however, is out of the scope of this paper.

South of Deoprayag Chail Nappe 3 overthrusts the Nagthat of the Parautochthonous Unit (FUCHS 1967, p. 89, Pl. 1). This thrust crosses the Pauri—Lansdowne road, 2 miles north of Satpuli (ibid, p. 92, Pl. 1), further SE we do not have information about the exact continuation of this thrust, which delimits the Parautochthonous Unit in the north. The approximate track given in Pl. 1 of this paper is concluded from the dips in RUPKE's map (1974) and geomorphological data.

About the Kosi area we have information by the report of G. KUMAR et al 1974 and own observations along the road from Ramnagar to Ranikhet. Between the Garhwal Syncline and its correlative the Naini Tal Syncline the Parautochthonous Unit is rather reduced. The unit consists entirely of Nagthat and Chandpur, except for a narrow scale of Blaini to Krol rocks along the Main Boundary Thrust. The Marchula Quartzite (KUMAR et al, 1974) is Nagthat, whereas Pauri Phyllite, Marithana Quartzite, and Manila Phyllite represent the Chail Formation and constitute Chail Nappe 3.

The Naini Tal Syncline was studied by MIDDLEMISS (1890), HEIM & GANSSER (1939), TEWARI & MEHDI (1964), PAL & MERH (1974), FUCHS & SINHA (1974) and others. The Naini Tal Syncline is composed by the sequence Nagthat to Krol. As in similar cases the lower formations are suppressed or are missing in the frontal part along the Main Boundary Thrust, but are well-developed in the north-eastern limb. The metabasic rocks of Bhowali and associated quartzites still belong to the Parautochthonous Unit. The succeeding phyllites and quartzites which accompany the Ramgarh granite-gneiss are part of the Chail Nappes. Not far SE of Naini Tal the Amritpur Granite and Ramgarh Porphyry reach the Main Boundary Thrust (B. N. RAINA & B. D. DUNGRAKOTI, 1975).

These authors regard the Amritpur Granite and the Ramgarh Porphyry as one intrusive complex. S. VARADARAJAN & R. S. RAWAT (1976) report intrusive contacts of the Amritpur Granite with the Bhim Tal quartzites and metabasics. A continuous igneous suite of spilite—keratophyre rocks is postulated by SHAH & MERH (1978). Our view is that the country rock adjoining the granite (and Ramgarh Porphyry) was either Ladhiya Formation (= Chail) and a thrust is concealed between these rocks and the Bhim Tal Formation. Or the Amritpur Granite forms really an intrusion in the series of the Krol Belt (Parautochthonous Unit), which would be a unique exception supporting the theory of Deep Seated Lineaments of SINHA (SINHA & JHINGRAN, 1977). Then a thrust is to be expected between the Amritpur Granite and the Ramgarh Porphyry, which definitely belongs to the Chail Nappes. Perhaps the first possibility seems more likely as no other instance is reported of a granite intrusive in the Krol Belt or the Parautochthonous Unit in general. From here to the Nepal Border the frontal portions of the Lesser Himalaya are formed by the Chail Nappes, and the

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

Parautochthonous Unit is missing. We think that the basic metavolcanics and quartzites associated with the Ramgarh granitoids in the Ladhiya region (RAINA & DUNGRAKOTI, 1975; VALDIYA, 1963) represent the Chail Formation of the Chail Nappes and do not form the continuation of the rock series of the Bhowali-Bhim Tal area. The latter are stratigraphically linked with the formations in the core of the Naini Tal Syncline and thus belong to the Parautochthonous Unit. In western Nepal in the Dailekh region the Parautochthonous Unit is observed again but is still very much reduced (FUCHS, 1974, 1977).

4. The Chail Nappes

PILGRIM & WEST (1928) coined the term Chail Nappe for a tectonic unit underlying the Jutoghs (Lower Crystalline Nappe, FUCHS, 1967). Also in the grade of metamorphism this nappe is between the medium to high grade crystallines overlying and the faintly altered lower units (Simla Slate Thrust Sheet, Krol Belt). It is characterized by the Chail Formation consisting mainly of clastic rocks, e. g. phyllites, quartzites, metaconglomerates, and basic metavolcanic intercalations. FUCHS (1967, 1975, 1977, FUCHS & FRANK, 1970) found this tectonic unit continuous all over the length of the Himalaya and extended the term Chail Nappe, coined in the Simla area, also to other Himalayan regions. The Chail Nappe may be composed by rather monotonous series, so in the type area. The Chail rocks in the Simla Klippe also contain acid metavolcanics and tuffaceous sandstone (ASHGIREI et al 1977). Acid orthogneisses in the Chails gave surprisingly old Rb/Sr ages, 1840 ± 70 my (FRANK et al, 1976) and 1430 ± 150 my (BHANOT et al, 1978). In western Nepal, however, the Chails are found in a succession of different formations. This sequence corresponds with the Simla Slate—Krol succession of the Krol Belt, except for certain facial peculiarities. The Chails take the position of the Chandpurs in that sequence (FUCHS, 1967; FUCHS & FRANK, 1970). After the stratigraphic order has been established repetitions of the succession made clear that the Chail Nappe consists actually of several subsidiary tectonic units. Frequently the stratigraphic sequence is reduced to Chail phyllites or quartzites and carbonates of the Shali-Deoban type. But also in these cases the experiences of Nepal teach us that Chails overlying the carbonates, which are younger, have come into this position by thrusting. This in our view is the key for the understanding of the tectonics of Garhwal and Kumaun.

In the Simla- and Chor area there is only one Chail Nappe, which is not very thick. The nappe overlies various formations and tectonic units, e. g. the Blainis, Jaunsars and Simla Slates of the Simla Slate Thrust Sheet, the Chandpurs, Nagthats, and even Krols of the Krol Belt (south of the Chor Mt.). ASHGIREI et al (1977) give a synthesis of regional metamorphism, K/Ar age datings, chemical and petrographic analysis and prove an independant tectonic entity of Chail (C 3) in Simla and Kulu area.

East of the Chor, in Garhwal, the situation is more complicated and the informations from that area give a picture not free of ambiguities (OLDHAM, 1883; PILGRIM & WEST, 1928; AUDEN, 1934, 1937; SRIKANTIA & BHARGAVA,

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

1974; RUPKE, 1974; PRASHRA et al, 1975; PRASHRA, 1976; VALDIYA, 1976). Our tentative view is certainly influenced by the experiences of FUCHS from Nepal:

The Chail Nappe, which at the base of the Chor crystallines may be traced to the north, is the highest unit (C 3) of the Chail Nappes. The Deobans and associated Chails (phyllites and quartzites), underlying this highest nappe, form lower subsidiary units of the Chail Nappe system. The highest member of the Deoban Formation of PRASHRA et al (1975) called Mandhali by PRASHRA (1976) and parts of the underlying tectonically mixed horizon represent Chail Nappe 2. The main mass of the Deoban Limestone following beneath that horizon and the underlying "Massive quartzite, shale, and slate" (PRASHRA et al, 1975) — correlative to Chail — form a still lower unit — Chail Nappe 1. This latter unit borders at steep or even reversed tectonic contact against the Simla Slates of Chakrata, which belong to the Parautochthonous Unit and consequently are tectonically lower. Certainly the rocks of Chail Nappe 1 have their source north of the site where the Parautochthonous Unit was deposited. But we have no information for how far a distance Chail Nappe 1 has moved to the south. So a parautochthonous nature of this lowest unit of the Chail Nappe system is quite likely [1]).

The great thickness of the Deobans of the type locality is partly due to tectonics as shown by Pl. 3. Towards the ESE the Deobans become thinner in the Yamuna section and pinch out somewhere east thereof. The NE dip observed in the Yamuna section and the higher tectonic position in respect to the rock series in the south is regarded as typical. The southern dip, reported from the Tons Valley we think to be reversed by later movements.

In the north at the Barni Gad junction and around the village Kuwa the lowest Deoban Limestone band is succeeded by black argillites, greenish phyllites, and several carbonate bands of Deoban type. The zone appears much disturbed and probably corresponds to the clastic series exposed in the wide dome of the Tons Valley. Two kilometers north of Kuwa, where the Yamuna Valley bends to the NE, several hundred meters of Chails (quartzites, metaconglomerates, phyllites, and chlorite schists) follow, which are succeeded by NE dipping Deoban carbonates. To the west these Chails join up with the tectonic horizon traced by PRASHRA (1976) in the Tons area. According to this author there are also Subathus found along the thrust plane. From PRASHRA's description it seems that there is a tectonic mixture of several formations along the thrust. The older formations (Simla Slates, Chails) of that horizon and the Chails observed in the Yamuna Valley together with the overlying Deoban carbonates make up Chail Nappe 2.

Above the Deobans again Chails follow, which form a pronounced syncline. The NW-SE axis of this syncline crosses the Yamuna Valley at Naugaon. The Chails filling the core of that syncline belong to Chail Nappe 3, the highest unit of the Chail Nappe system. Within the Chails of Chail Nappe 3 there are also

[1]) The Chail Units C 1, 2, 3 are entirely the concept of FUCHS. SINHA holds different view regarding Chail as geosynclinal deep water facies of a separate structural facial zone with acid volcanism.

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

granitoids reported from Purola (A. K. PACHAURI, 1972) or west of Tiuni in the Tons Valley (PRASHRA, 1976, Pl. 2). The syncline is a very persistent structural element, which may be followed through Garhwal and finally joins up with the Dudatoli—Almora Syncline of Kumaun (Pl. 1, 2). NE of Naugaon Deoban Limestone, reduced to a band of ca. 50 m, crosses the valley. This SW dipping Deobans represent the top of Chail Nappe 2, which comes up again NE of the Naugaon Syncline.

The limestone band was traced to the north, where the dip turns to west (PACHAURI, 1972). The Chail Formation and metabasic rocks (SINHA & BAGDASARIAN, 1976; SINHA in ASHGIREI et al, 1977) of the Barkot area underlie the above Deoban Limestone in normal stratigraphic order, together constituting Chail Nappe 2..

At Gangani PACHAURI reports an anticline of Deoban carbonates coming up from beneath, his Bhankali—Barkot Formation (= Chails). Certainly PACHAURI is right when he correlates the Gangani carbonates with those south of Barni Gad. It is Deoban of Chail Nappe 1, which reappears in a window beneath Chail Nappe 2. This nappe is rather reduced in the north-eastern limb of the Gangani Anticline and the metabasics and PACHAURI's Hudoli Formation (= Chail), making up Chail Nappe 3, almost come in contact with the Deoban of Chail Nappe 1 (PACHAURI, Fig.. 1; Pl. 1, 2, of present paper). Chail Nappe 3 forms a syncline and NE thereof Chail Nappe 2 appears in a window. The latter forms the north-western end of the Uttarkashi Window, which just reaches the Yamuna Valley (JAIN, 1971, Fig. 7, 8). NE of that last updoming the Chails of Chail Nappe 3 — mainly quartzites and basic metavolcanics (SINHA personal observations) — dip beneath the Crystalline Nappes following above the Main Central Thrust.

It should be emphasized that the quartzites, phyllites, and metabasics (= Chail) directly underlying the Crystalline are a typical phenomenon for all the Himalaya. Nowhere there is an indication of roots of a "Krol Nappe", which should be expected somewhere below the Crystalline, if the Krol Nappe hypothesis and the existence of the "Tons Thrust" are accepted.

As mentioned above the rock zones of the Yamuna Valley may be followed to the SE into the Bhagirathi Valley. The latter area was recently investigated by A. K. JAIN (1971) and N. C. AGARWAL & G. KUMAR (1973). The quartzite—basic metavolcanics complex (= Chail), which is directly overthrust by the Crystalline Nappes, frames the window of Uttarkashi. In that window Deoban carbonates are exposed together with quartzites, phyllites, and metavolcanic rocks. These beds represent the Chail-Deoban sequence of lower subsidiary units of the Chail Nappes (C 2, possibly also C 1).

Down the Bhagirathi we come again across a complicated zone at the village Dunda. There the SW dipping Chail quartzites and metabasics, which close the Uttarkashi Window in the SW, show NE dips. From beneath them appears an anticline consisting of carbonates, phyllites, quartzites, metabasics and a lense of augen granite-gneiss. This much disturbed rock belt represents Chail (metabasics, quartzites, greenish phyllites) Shali Slates (black argillites), Blainis (red and green phyllites and arenites) and the typical granitoids intrusive in Chail. Tectonically

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

the Khattukhal Limestone seems to have the position of the carbonates of Gangani in the Yamuna Valley, that means it represents an anticline of Chail Nappe 1. The Chails surrounding it (Dunda Quartzite, Dhanari Slates in part, Gamri Quartzite, JAIN, 1971) belong to Chail Nappe 2 and join up with the Chails of the Barkot area of Yamuna. The Deoban carbonates of the Shyalna occurrence follow conformably above these Chails and consequently also belong to Chail Nappe 2. Our observations suggest that the Shyalna limestone joins up with the limestone band NE of Naugaon. The above carbonates are tectonically succeeded by steeply dipping Chails mainly argillites and some metabasics, which crop out all along the Khurmola Gad. Around Dharasu these Chails contain rather massive siltstones reminding of those in the Chandpurs north of the Sauri Gad—Yamuna junction. Obviously there is resembling facies in formations of same age, but belonging to quite different structural units (Parautochthonous Unit, Chail Nappe 3). The Chails, which overthrust the Shyalna carbonates respectively the Gamri Quartzite, form a huge syncline reaching south into the Nagon Gad (JAIN, 1971). This Dharasu Thrust Sheet of JAIN (1971) is the continuation of Chail Nappe 3 met in the syncline of Naugaon in the Yamuna Valley. It ist significant that this highest of the Chail Nappes apparently overlaps the lower units observed in the Yamuna Valley and comes in contact with the lower formations of the Parautochthonous Unit (Krol Belt) in the Nagon Valley. Further SE it comes in touch even with the Krol (see Pl. 1, 2).

Here we should deal with the outliers in the core of the Mussoorie Syncline. AUDEN (1937) found these klippes of his Garhwal Nappe (Satengal, Banali) and subdivided them into a lower Bijni- and higher Amri Nappe. JAIN (1972) restudied these klippes. This author also discerns two nappes the Saklana Thrust Unit and Ringalgarh Thrust Unit. The first one shows the succession from bottom to top: Ghena Slate, Danchula Quartzite, Satengal Limestone. Separated by the Ringalgarh Thrust follows the Banali Formation (= Chail). We do not doubt that the upper unit corresponds to our Chail Nappe 3. The rock series of the lower unit probably correlate to the Lower Bijni Nappe (SHANKER & GANESAN, 1973).

In the Garhwal Syncline, adjoining in the SE, the Chail Nappes form a huge outlier. It was again AUDEN who recognized the nappe structure. SHANKER & GANESAN (1973) subdivide the "Garhwal Nappe", overlying the Tals and Subathus of the Parautochthonous Unit, into Lower Bijni Unit, Upper Bijni Unit, and Amri Unit. The lowest of these units is of great interest, as it contains fossiliferous Permo-Carboniferous beds. The basal "quartzite and slate-phyllite member" corresponds with Chail. It is succeeded by the "Boulder-Slate member", which by its lithology and fossil content resembles the Agglomeratic Slate of Kashmir-Chamba. GANESAN (1972) tentatively extends the Upper Palaeozoic age of the boulder slate of the Lansdowne area to the Blainis and Mandhalis, a view favoured also by FUCHS. The "Gritty quartzite member" consists of pebbly siltstones and quartzites and is succeeded by the "Sandy limestone member", which may correspond to the Satengal Limestone of the Satengal Klippe. In our view this is one of the rare occurrences, where the tilloid series of the Lesser Himalayas are proved Upper Palaeozoic by fossil evidence. Obviously the series

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

was deposited on Chail Formation and belongs structurally to one of the lower subsidiary units of the Chail Nappes. Definitely the fossiliferous beds are of Lesser Himalayan origin and have quite different position as the similar formations of Kashmir and Chamba, which overlie the Crystallines and thus represent southern portions of the Tethys Zone.

The Upper Bijni Unit comprises phyllites and quartzites resembling Nagthat (AUDEN, 1937; SHANKER & GANESAN, 1973), which may also contain parts of the Chail Formation (FUCHS).

The Amri Unit without doubt is identical with Chail Nappe 3. This nappe overlaps the lower Chail units such as in the Yamuna-Bhagirathi region (see Pl. 1, 2). The Lansdowne Granite is one of the deformed granitoid intrusions so characteristic for the Chails (e. g. in Kishtwar Window, Dhauladhar-, Ramgarh Granites etc.).

After dealing with the outliers of Chail Nappes, which are preserved in synforms of the Parautochthonous Unit, we return to the wide belt formed by the Chail Nappes in the north. As previously described in this paper Chail Nappe 3 overlaps the lower Chail Nappes and various formations and structural elements of the Parautochthonous Unit. Thus Chail Nappe 3 shows a definitely unconformable relation to the underlying units. The axis of the synform in which Chail Nappe 3 is preserved strikes strictly NW-SE from Naugaon in the Yamuna Valley to Tehri and right to the Dudatoli. Thus the synform strikes obliquely to the WNW—ESE strike prevalent in the Tons—Mussoorie area (see Pl. 1).

From Dharasu to the region of Tehri south-western dip at medium angles dominates in the north-eastern limb of the syncline of Chail Nappe 3. This portion of Chail Nappe 3 (Dharkot Thrust Sheet, SAKLANI, 1972) consists mainly of phyllites (Gwar Phyllite, SAKLANI, 1971, 1972). Below the delimitating thrust (Dharkot Thrust, SAKLANI, 1971) there is a folded belt of Chails (Pratapnagar Quartzite, Jakhnidhar Schist), Nagthats (Paturi Quartzite), Blainis (Bhainga Slate) and Shali-Deoban (Bhelunta Limestone). The SW directed folds appear unconformable to the overlying Chail Nappe 3 dipping SW. According to SAKLANI (1971, 1972) the main mass of the Pratapnagar Quartzites overrides the belt of carbonate rocks from the NE. This might indicate that the latter zone represents Chail Nappe 1 and correlates with the Khattukhal- and the Gangani carbonates of Bhagirathi respectively Yamuna Valleys. SAKLANI's Pratapnagar Thrust Sheet would be Chail Nappe 2 in this case. From JAIN's map (1971, Fig. 1) and partly also from SAKLANI's maps (1971, Fig. 1, 2; 1972, Fig. 1) it is suggested that the carbonates and the Pratapnagar Quartzite formed one stratigraphic succession, which was later disturbed by the Pratapnagar Thrust. This would mean that both belong to Chail Nappe 2 and the carbonates correspond with the Shyalna carbonate occurrence. There is a vast terrain built by quartzites and basic metavolcanics to the NE of the carbonate belt described. Definitely these series — Gamri Quartzite (JAIN, 1971), Pratapnagar Quartzite (SAKLANI, 1972) are identical with Chail. In absence of marker horizons such as the carbonates mentioned, it is difficult to decide whether they belong to Chail Nappes 2 or 3. From the material, quartzitic or phyllitic Chails, a decision is not possible as the facies changes very rapidly along or across the strike.

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

The folded rock belt of the Pratapnagar area continues towards the SE and our observations along the Bhilangna Valley fit well with SAKLANI's observations from the first named region. Along the east-west course of the Bhilangna east of Tehri there are monotonous Chail phyllites of Chail Nappe 3 dipping uniformly SW. At a thrust — the continuation of the Dharkot Thrust — the above phyllites overlie a NE dipping sequence of Chail quartzites (ca. 100 m), multicoloured phyllites and quartzites (= Nagthat—Blaini, 20—30 m) and Deoban dolomite (60—80 m), the latter being rather vertical. Near the village Asena again Chail phyllites and quartzites follow dipping NE (ca. 200 m). They are succeeded by a band of Deoban dolomite. Above these carbonates follows a thick pile of folded Chail quartzites, dipping moderately NNE. The section shows again the unconformable relation of Chail Nappe 3 to the lower structural units. As in the Pratapnagar area there is also uncertainly here whether Chail Nappe 3 overrides discordantly a contorted belt consisting of Chail Nappes 1 and 2 or only Chail Nappe 2. In this latter case the sequence of Chail Nappe 2 is complicated by scale structures of more local importance.

Further east we have good information about the geology of the Alaknanda region (HEIM & GANSSER, 1939; AUDEN, 1949; FUCHS, 1967; KUMAR, PRAKASH & SINGH, 1974; RUPKE, 1974; KUMAR & AGARWAL, 1975 and others). In the Alaknanda section we find the widest extention of the Chail Nappes. The front of the Chail Nappes crosses the Ganges Valley south of Deoprayag and the Western Nayar River north of Satpuli. There Chail Nappe 3 overrides Nagthats (Saknidhar Formation, KUMAR et al, 1974), which belong to the Parautochthonous Unit and form the north-eastern limb of the Garhwal Syncline. From south Deoprayag up the Alaknanda to north of Srinagar the Chails are predominantly phyllitic (Pauri Phyllite, KUMAR et al, 1974). These rocks are part of the great synform of Chail Nappe 3, which we have traced from Naugaon in the Yamuna Valley. The Pauri Phyllites are succeeded by quartzites (Khirsu — Maithana) and by a phyllite-quartzite complex (Manila). Above these various developments of the Chail Formation follows the Dudatoli Crystalline filling the core of the great synform.

North of Srinagar Chail Nappe 3 is terminated by the Srinagar Thrust, which, however, is not the continuation of the North Almora Thrust as assumed by KUMAR et al (1974). The latter thrust swings around at the base of the Dudatoli Crystalline and joins with the South Almora Thrust. The Srinagar Thrust clearly is the continuation of the Dharkot Thrust (SAKLANI, 1971) and Dharasu Thrust (JAIN, 1971), which is rightly indicated in VALDIYA's map (1976). Further SE a series of carbonate occurrences of Chail Nappe 2 are found below the thrust, the latter may be followed to Dwarahat.

From the Srinagar Thrust to south of Nandaprayag all the country seems to belong to Chail Nappe 2. From KUMAR & AGARWAL (1975) and HEIM & GANSSER (1939) we know that complexes of quartzite and basic metavolcanics predominate over phyllites — both representing the Chail Formation. In the named formation there are various bodies of granite-gneiss. The carbonate occurrences (Sera, Lameri, Dobri, Langasu etc.) are Deoban-Shali rocks, which are in stratigraphic connection with the surrounding Chails. These series are disturbed by

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

folding and scale structures (e. g. "Alaknanda Fault" KUMAR & AGARWAL, 1975).

The Patroli Quartzite follows tectonically above the various rock series of Chail Nappe 2 and represents Chail Nappe 3. This unit forms a syncline, with the axis crossing the Alaknanda Valley at Maithana (KUMAR & AGARWAL, 1975). NE of that syncline an anticline brings up a thick carbonate complex in the Chamoli Window (HEIM & GANSSER, 1939; AUDEN, 1949). These carbonates no doubt are Shali—Deobans, tectonically belonging to lower Chail units. But it is difficult to decide whether they are Chail Nappe 1 or 2. HEIM & GANSSER (1939, p. 50) report about a second band of crystalline carbonates, intercalated in the Chails overlying the main mass of Deoban. This might indicate that the central parts of the window represent Chail Nappe 1, the named carbonate band marking the top of Chail Nappe 2. The uncertainty mentioned above is common to all the carbonate windows of eastern Kumaun. There apparently only Chail Nappe 3 is clearly defined, which consists of the quartzites, phyllites, and basic metavolcanics (Berinag) and overthrusts a lower sub-unit of the Chail Nappe System, composed of carbonates and argillites.

The Chamoli Window is the north-western most of a series of three windows exposed in a large antiformal belt. East of a small window in the Nandakini Valley we find a wide area composed of carbonate rocks in the Kapkot-Tejam belt. The pioneer work done by HEIM & GANSSER (1939) was recently succeeded by studies of R. C. MISRA & D. M. BANERJEE (1968), A. R. BHATTACHARYA (1971), A. R. PANDEY (1971), R. C. MISRA & A. R. BHATTACHARYA (1972), A. AHMAD (1975), and D. M. BANERJEE & P. C. BISARIA (1975).

There is no doubt that the stromatolitic dolomites and limestones, which have been given different names, are identical with Deoban and Shali. The multi-coloured beds in the Sor Slates seem to represent the Blaini, the carbonaceous rocks correspond to the Shali Slates and Infra Krols. The Hatsila Formation apparently comprises Nagthat to Blaini. The named formations are folded, but in stratigraphic contact with each other. From PANDEY's paper (1971) it seems possible that Chails are intercalated in the higher portions of the carbonates, which might indicate major disturbances near the top.

The Berinag Quartzites and associated metabasics overlie the described rock series with a thrust contact. They form Chail Nappe 3, which in turn is succeeded by the Crystalline Nappes.

North of Dharchula, near the Nepal border an outlier of the Crystallines makes the Tejam Window bifurcate (VALDIYA, 1976). According to the observations of A. K. SINHA the carbonates of the Sirdang Zone north of that Crystalline outlier become narrow towards the west and probably pinch out [2]). Anyhow, there is no doubt that the carbonates of the Sirdang Window correspond with the main mass of carbonates of the Tejam Window. The Sirdang carbonates are mantled by the Chails of Chail Nappe 3, both units are exposed in an anticline overturned towards the SW.

The Tejam Window is terminated in the SW by Berinag Quartzites (=Chails) of Chail Nappe 3 and outliers of the Crystalline Nappes (Baijnath, Askot),

[2]) A detailed investigation is to be taken in summer 1978 by SINHA.

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

which are preserved in a major synform. South of Baijnath Chail Nappe 3 contains bodies of intrusive granite-gneiss besides the very common basic metavolcanics.

South of the named synform the carbonates and associated formations are brought up again in a wide antiform known as Pithoragarh Zone. This belt was recently investigated by R. C. MISRA & K. S. VALDIYA (1961), VALDIYA (1962, 1965, 1968) and R. C. MISRA & D. M. BANERJEE (1968). Sor Slates and the overlying dolomites and limestones make up a lower unit of the Chail Nappe system. They form two anticlines separated by an outlier of Chail Nappe 3, which ends north of Pithoragarh. East thereof the separating syncline is marked by the Gangolihat Dolomites (= Shali, Deoban). All these folds are overturned towards SW. The southern anticline reaches the Kosi Valley at Someshwar, where the Pithoragarh Window plunges westwards beneath the Chails of Chail Nappe 3.

South of the Pithoragarh Zone there is the wide synform of Almora, where the Crystalline Nappe is preserved in a large outlier. South of this synform the Chail Nappes reappear, consisting of Chails (Ladhiya Formation, VALDIYA, 1963) and the Ramgarh Porphyry. The carbonate band (Betalghat Formation, RAINA & DUNGRAKOTI, 1975) indicates that there are more units of the Chail Nappe system. As mentioned in chapter 3 we think that the Amritpur Granite forms one intrusive complex with the Ramgarh Porphyry in the sense of RAINA & DUNGRAKOTI (1975). This implies that the volcanics and quartzites injected by that granite (VARADARAJAN & RAWAT, 1976) belong to the Ladhiya Formation (= Chail) and are separated by a thrust from the very similar series of Bhim Tal-Bhowali, which are Nagthats of the Krol Belt. However, that problem is not yet solved.

From Amritpur to the Nepal border the front of the Lesser Himalayan units is formed by the Chail Nappes, which override the Siwaliks along the Main Boundary Thrust.

5. The Crystalline Nappes

In this chapter we shall give just a few general remarks as we personally have not worked on these units in the region of Garhwal-Kumaun, except some hurriedly taken traverses.

It ist a fact proved by all authors working in the Lesser Himalayas that the high grade metamorphic rocks always are in physically highest position: The Chor crystallines overlie the less altered units in the west, south and east. The Baijnath, Askot, Dudatoli-Almora crystallines are found in the cores of large synforms. This observation is very suggestive of nappes and therefore most authors followed PILGRIM, WEST, AUDEN, HEIM and GANSSER, who explained the above relations by large scale thrust movements. Recently this was contested by KUMAR et al (1974), S. P. SAXENA (1974, 1975, 1976). From the experience from adjoining parts of Himalaya and from the Alps we fully agree with VALDIYA (1976) who still does not doubt the existence of nappes in the Lesser Himalaya.

Certainly VALDIYA is also right in dividing the Crystalline into lower "Jutogh-Munsiari-Almora Nappes" and a higher "Vaikrita" unit. We too discerned a

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

lower unit of medium grade alteration and an upper unit composed of medium to high grade metamorphosed rocks (FUCHS, 1967, 1974, 1975, 1977; FUCHS & FRANK, 1970). The occurrence of sillimanite bearing rocks in the Dudatoli-Almora outlier (K. N. SINGH, 1976), however, shows that both the above units compose some of the outliers. The distinction probably is not easy in some cases. VALDIYA's concept of two thrusts, viz. M. C. T. and Vaikrita, is doubted by SINHA, who thinks the so-called Vaikrita Thrust in many sections of Garhwal and Kumaun to be rather high angle faults.

6. Conclusions

The Tertiary Zone, consisting mainly of the Siwaliks, is overridden by the various units of the Lesser Himalaya along the Main Boundary Thrust. We do not think that in depth this structural plane merges into a low angle thrust. SINHA & JHINGRAN (1977) take the M. B. T. as a steep angle tectonic lineament. The southern portions of the Lesser Himalaya are regarded to be sheared off from their original base but are still in a parautochthonous position. The existence of some windows is evidenece that the frontal portions of the Krol Belt are allochthonous. But this does not imply that a "Krol Nappe" is derived somewhere from the far north. Contrary to many authors we repudiate the "Krol Nappe" hypothesis and FUCHS takes the Tejam—Deoban belts to be tectonically higher than the Krol Belt. This is consistent with the general observation that the grade of alteration increases from lower to higher units and the Deobans and associated formations do show the higher metamorphism. Furthermore there are no traces of a "Krol Nappe" over the Deobans, or roots of such a nappe north of the Deoban—Tejam belt. We regard this zone as part of the Chail Nappe system, whereas most authors suppose it to be autochthonous. Concerning the lowest unit we too consider a parautochthonous nature. The lowest unit is derived from immediately north of the Krol Belt and has marginally overridden the latter. The higher Chail units, however, are true nappes [3]). The repetition of clastic and carbonate formations is not stratigraphic but tectonic Particularly the phyllites or quartzite-metavolcanic complexes overlying the carbonates have gained their position by thrusting. Up to three subsidiary units are discerned, the upper two definitely being nappes. The uppermost, Chail Nappe 3, overlaps the lower units and several formations of the Parautochthonous Unit (Krol Belt), thus showing tectonic unconformity. The Chail Nappe system is succeeded by the Crystalline Nappes. Thus the thrust movements brought about the well-known phenomenon of the "reversed metamorphism".

After the main phase of thrusting (post Dagshai) the whole pile of parautochthonous units and nappes was compressed, leading to folding and local wedge structures. In that phase probably the Main Boundary Thrust came into being, when the Lesser Himalayan units moved "en bloc" over the north-eastern portions of the Tertiary belt (view of FUCHS). SINHA & JHINGRAN (1977) take the

[3]) Both authors take C 3 as a true nappe, whereas SINHA holds view that the Calc-Zone of Shali-Deoban-Tejam is older (Riphean) and Krol is Mesozoic.

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

M. B. T. as a very old deep seated lineament. The folding led to the formation of windows in anticlines and of outliers of higher nappes in the synclines. These anti- and synclines are crossed by zones of axial depression or culmination roughly in north-south direction. The Chor area is a typical zone of axial depression. To the east follows a culmination zone in the Tons region. Further SE there is a slight axial plunge towards SE, and therefore more and larger outliers of higher nappes occur in that direction. Hand in hand with that the lowest unit of the Lesser Himalaya — the Parautochthonous Unit — becomes more and more reduced and finally disappears ESE of Naini Tal.

Faults also influenced the structure of Garhwal—Kumaun, but to a minor degree. Faults probably traverse the fold structures in the sectors Bhowali—Dwarahat and Ladhiya Valley—Someshwar—Baijnath. In the south-western limb of the Lansdowne Syncline traverse faults seem to be effective (see fig. 1, SHANKER & GANESAN, 1973). The Aglar Fault in the northern limb of the Mussoorie Syncline is approximately parallel to the strike of the rocks.

In the foregoing we gave a picture of the Lesser Himalayan structure of Garhwal and Kumaun. Certainly this picture is tentative, a series of details are yet to be cleared and in several points the authors hold different views. Definitely there will be also much criticism, as it is felt as a sacrileg if the existence of the "Krol Nappe" or "Tons Thrust" are doubted. But we are convinced that the principal features of our thesis are consistent with nature. Anyhow, we hope that the ideas presented might be fruitful for further research in that part of Himalayas.

Acknowledgement

For FUCHS the travel expenses for the 1976 trip were covered partly by the "Fonds zur Förderung der wissenschaftlichen Forschung in Österreich" the "Kulturamt der Stadt Wien" and by the Indian Government. The latter had invited FUCHS to participate at the Himalayan Geology Seminar held in New Delhi 1976. To all the named institutions we are highly indebted for their financial support. The "Ministerium für Wissenschaft und Forschung" has made possible our research by granting special leave to FUCHS. The named author is also very grateful to Hofrat Prof. Dr. F. RONNER, Director of the Geological Survey of Austria for his assistance. Dr. S. C. D. SAH, Director of Wadia Institute of Himalayan Geology, kindly has provided the facilities for the joint field trip of the authors in 1976, who are very grateful for this help. SINHA takes opportunity to extend his sincere gratitude to Shri S. P. NAUTIYAL, President of Wadia Institute of Himalayan Geology, for his encouragement to come out with researches mooted with new ideas and concepts.

References *)

AGARWAL, N. C.: Discovery of Bryozoan Fossils in the Calcareous Horizon of Garhwal Group, Pauri-Garhwal District, U. P. — Himal. Geol., 4, p. 600—618, Delhi 1974.

AGARWAL, N. C., & KUMAR, G.: Geology of the Upper Bhagirathi and Yamuna Valleys, Uttarkashi District, Kumaon Himalaya. — Himal. Geol., 3, p. 1—23, Delhi 1973.

*) G. S. I. = Geological Survey of India.

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

AHMAD, A.: Geology and Structure of the Area North of Bageshwar, District Almora, Uttar Pradesh. — Himal. Geol. 4, p. 207—235, Delhi 1974.

ASHGIREI, G. D., SINHA, A. K., PANDE, I. C., & MALLIK, B. C.: A contribution to the Geology, Geochronology and History of Regional Metamorphism of Himachal Himalaya. — Himal. Geol., 7., p. 102—117, Delhi 1977.

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

AUDEN, J. B.: The Structure of the Himalaya in Garhwal. — Rec. G. S. I. 71 (4), p. 407—433, Calcutta 1937.

AUDEN, J. B.: Tehri Garhwal and British Garhwal (in Gen. Rep. for 1939). — Rec. G. S. I. 78 (1), p. 74—78, Calcutta 1949.

BANERJEE, D. M., & BISARIA, P. C.: Stratigraphy of the Bageshwar Area — A Reinterpretation. — Himal. Geol. 5, p. 245—260, Delhi 1975.

BERTHELSEN, A.: A Geological Section through the Himalayas. A Preliminary Report. — Bull. Geol. Soc. of Denmark, 12 (1), p. 102—104, Copenhagen 1951.

BERTHELSEN, A.: A discussion of the structures and the stratigraphy of the Lower and Higher Himalayas of the Simla—Sutlej section. — Paper read at People's Friendship University, Moscow, May 1967.

BHANOT, V. B., KWATRA, S. K., KANSAL, A. K., & PANDEY, B. K.: Rb-Sr whole rock age for Chail series of northwestern Himalaya. — Jour. Geol. Soc. India, vol. 19, no. 5, p. 224—225, Bangalore 1978.

BHARGAVA, O. N.: A Reinterpretation of the Krol Belt. — Himal. Geol. 2, p. 47—81, Delhi 1972.

BHATTACHARYA, A. R.: Petrographic Studies of the Carbonate Rocks of the Calc Zone of Tejam Around Kapkot, District Almora, U. P. — Himal. Geol. 1, p. 288—295, Delhi 1971.

DUTTA, K. K., & KUMAR, G.: Geology of the Dehra Dun—Musoorie—Chakrata Area (Guide to Excursions). — 22th Int. Geol. Congr., 17 pp., New Delhi 1964.

FRANK, W., THÖNI, M., & PURTSCHELLER, F.: Geology and Petrography of Kulu- South-Lahul Area. — Colloqu. Intern. C. N. R. S. No 268, Écologie et Géologie de l'Himalaya, p. 147—172, Paris 1976.

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

FUCHS, G.: On the Geology of the Karnali and Dolpo Regions, West Nepal. — Mitt. Geol. Ges. Wien, Vol. 66—67, p. 21—32, Wien 1974.

FUCHS, G.: The Geology of the Karnali and Dolpo Regions, Western Nepal. — Jb. Geol. B.-A. 32, p. 1—59, Wien 1975.

FUCHS, G.: The Geology of the Himalayas in Synoptic View. — Colloqu. Intern. C. N. R. S. No 268, Écologie et Géologie de l'Himalaya, p. 173—180, Paris 1976.

FUCHS, G.: The Geology of the Karnali and Dolpo Regions, Western Nepal. — Jb. Geol. B.-A. 120 (2), p. 165—217, Wien 1977.

FUCHS, G., & FRANK, W.: The Geology of West Nepal between the Rivers Kali Gandaki and Thulo Bheri. — Jb. Geol. B.-A., Sdb. 18, p. 1—103, Wien 1970.

FUCHS, G., & SINHA, A. K.: On the Geology of Naini-Tal (Kumaun Himalaya). — Himal. Geol. 4, p. 563—580, Delhi 1974.

GANESAN, T. M.: Fenestellid bryozoa from the boulder slate sequence of Garhwal. — Himal. Geol. 2, p. 431—451, Delhi 1972.

GANSSER, A.: Geology of the Himalayas. — Interscience Publishers John Wiley and Sons Ltd., p. 1—289, London, NewYork, Sydney 1964.

GUPTA, V. J.: A Note on the Stratigraphic Position of the Sirdang Quartzites of the Type Area, Kumaon Himalayas. — Verh. Geol. B.-A., p. 263—264, Wien 1972.

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

JAIN, A. K.: Stratigraphy and Tectonics of Lesser Himalayan Region of Uttarkashi, Garhwal Himalaya. — Himal. Geol., 1, p. 25—58, Delhi 1971.

JAIN, A. K.: Structure of Bidhalna—Pharat Windows and Garhwal Thrust Unit, Garhwal, U. P. — Himal. Geol. 2, p. 188—205, Delhi 1972.

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

KUMAR, G., & AGARWAL, N. C.: Geology of Srinagar—Nandprayag Area (Alaknanda Valley), Chamoli, Garhwal and Tehri Garhwal Districts, Kumaun Himalaya, Uttar Pradesh. — Himal. Geol. 5, p. 29—59, Delhi 1975.

KUMAR, G., PRAKASH, G., & SINGH, K. N.: Geology of the Deoprayag — Dwarahat Area, Garhwal, Chamoli and Almora Districts, Kumaun Himalaya, Uttar Pradesh. — Himal. Geol. 4, p. 323—347, Delhi 1974.

MIDDLEMISS, C. S.: Physical Geology of West British Garhwal; with Notes on a Route Traverse through Jaunsar Bawar and Tiri-Garhwal. — Rec. G. S. I. 20 (1), p. 26—40, Calcutta 1887 a.

MIDDLEMISS, C. S.: Crystalline and Metamorphic Rocks of the Lower Himalaya, Garhwal, and Kumaon. — Rec. G. S. I. 20, pt. 3., p. 134—143, pt. 4., p. 161—167, Calcutta 1887 b.

MIDDLEMISS, C S.: Crystalline and Metamorphic Rocks of the Lower Himalaya, Garhwal, and Kumaon, Section III. — Rec. G. S. I., 21 (1), p. 11—28, Calcutta 1888.

MIDDLEMISS, C. S.: Physical Geology of the Sub-Himalaya of Garhwal and Kumaun. — Mem. G. S. I. 24 (2), p. 81—142, Calcutta 1890.

MISRA, R. C., & BANERJEE, D. M.: Stratigraphy, correlation and tectonics of Sarju-Pungar valley areas, Districts Almora-Pithoragarh, U. P. — Publ. Centr. Adv. Stud. Geol. Panjab Univ. 5, p. 101—113, Chandigarh 1968.

MISRA, R. C., & BHATTACHARYA, A. R.: Geology of the Area around Kapkot, District Almora, Uttar Pradesh. — Himal. Geol. 2, p. 252—270, Delhi 1972.

MISRA, R. C., & VALDIYA, K. S.: The Calc Zone of Pithoragarh, with Special Reference to the Occurrence of Stromatolites. — J. Geol. Soc. Ind. 2, p. 78—90, Bangalore 1961.

NAUTIYAL, S. P.: Almora District. — Rec. G. S. I. 79 (1), p. 375, Calcutta 1953.

OLDHAM, R. D.: Note on the Geology of Jaunsar and the Lower Himalayas. — Rec. G. S. I. 16, p.. 193—198, Calcutta 1883.

PACHAURI, A. K.: Stratigraphy, correlation and tectonics of the area around Purola, Uttarkashi and Dehra Dun Districts (U. P.). — Himal. Geol. 2, p. 371—387, Delhi 1972.

PAL, D., & MERH, S. S.: Stratigraphy and Structure of the Naini Tal Area in Kumaun Himalaya. — Himal. Geol. 4, p. 547—562, Delhi 1974.

PANDEY, A. R.: A Preliminary Geological Report of Baijnath Area, Almora, U. P. — Himal. Geol. 1, p. 266—275, Delhi 1971.

PASCOE, E. H.: A Manual of the Geology of India and Burma. — Vol. 2, p. 1—1343, 3rd Edition Govt. Press, Calcutta 1959.

PILGRIM, G. E., & WEST, W. D.: The Structure and Correlation of the Simla Rocks. — Mem. G. S. I., 53, p. 1—140, Calcutta 1928.

PRASHRA, K. C.: Recent Observations on Mandhali Formation and Simla Slate—Tertiary Sequence in the Tons Region of Garhwal. — Intern. Himal. Geol. Seminar, New Delhi 1976.

PRASHRA, K. C., KHANNA, P. C., & SRIVASTAVA, R. N.: Note on the Lithostratigraphy of the Deoban Formation. — G. S. I. Misc. Publ. No 24, p. 56—58, Calcutta 1975.

RAINA, B. N., & DUNGRAKOTI, B. D.: Geology of the Area between Naini Tal and Champawat, Kumaun Himalaya, Uttar Pradesh. — Himal. Geol. 5, p. 1—27, Delhi 1975.

RAMJI: Stratigraphy and Structure of the Garhwal Group in Parts of Almora and Pithoragarh District, Uttar Pradesh. — Intern. Himal. Geol. Seminar, New Delhi 1976.

RAO, A. R.: On the Krol Nappe Hypothesis. — J. Geol. Soc. India 9 (2), p. 153—158, Bangalore 1968.

RUPKE, J.: Stratigraphic and Structural Evolution of the Kumaon Lesser Himalaya. — Sedimentary Geology 11, No 2—4, p. 81—265, Elsevier. Scient. Publ. Co., Amsterdam 1974.

SAKLANI, P. S.: Fold patterns in the Krol Nappe formations of the Pratapnagar area, Garhwal Himalaya. — 57th Ind. Sci. Cong. (Abst.), p. 208, 1970.

SAKLANI, P. S.: Structure and Tectonics of the Pratapnagar Area, Garhwal. — Himal. Geol. 1, p. 75—91, Delhi 1971.

SAKLANI, P. S.: Lithostratigraphy and Structure of the Area between the Bhagirathi and the Bhilangna Rivers, Garhwal Himalaya. — Himal. Geol. 2, p. 342—355, Delhi 1972.

SAXENA, S. P.: Geology of the Marchula-Bhikiasen Area, District Almora, Uttar Pradesh, with Special Reference to the South Almora Thrust. — Himal. Geol. 4, p. 630—647, Delhi 1974.

SAXENA, S. P.: Geology, Structure and Tectonics in Part of Kumaun and Garhwal Himalaya, U. P.: A Review. — Intern. Himal. Geol. Seminar, New Delhi 1976.

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

SAXENA, S. P., & RAO, P. N.: Does Almora Nappe exist? — Himal. Geol. 5, p. 169—184, Delhi 1975.

SHAH, O. K., & MERH, S. S.: Structural Geology and Stratigraphy of Bhimtal-Bhowali area in Kumaun Himalaya — A Reinterpretation. — J. Geol. Soc. India, vol. 19, no. 3, p. 91—105, Bangalore 1978.

SHANKER, R., & GANESAN, T. M.: A Note on the Garhwal Nappe. — Himal. Geol. 3, p. 72—82, Delhi 1973.

SHARMA, R. P.: Elucidation of Structure and Stratigraphy of Deoban Belt, North of the Tons River in H. P., Himalaya. — Proceedings of Appreciation Seminar on use of Air Photo-Interpretation in Survey and Mapping of Natural Resouces, Indian Photo-Interpretation Institute, Dehra Dun (a collection of cyclostyled papers). — 9 p., 1972.

SHARMA, R. P., & VIRDI, N. S.: Tectonic Evolution of Simla and Kumaon Himalaya, based on Landsat-I Multispectral Imagery and Aerial Photo Interpretation. — Intern. Himal. Geol. Seminar, New Delhi 1976.

SINGH, K. N.: The Relation of Gneissic Complex to Regional Metamorphism in Parts of Dudhatoli Area, Districts Pauri and Chamoli, Uttar Pradesh. — Intern. Himal. Geol. Seminar, New Delhi 1976.

SINGH, M. P.: A Reappraisal of the Geology of the Kalsi—Chakrata Area, Uttar Pradesh and the Problem of Blaini Mandhali Correlation. — Bull. Ind. Geol. Assoc. 8 (2), p. 118—142, Chandigarh 1975.

SINHA, A. K.: Tectonic position, lithology and age of Autochthonous Simla and Shali Series and the problem of Jaunsar, Blaini, Infra Krol, Krol and Tal Tectonic Unit in the Himalaya (India). — Unpublished Ph. D. Thesis Peoples' Friendship University, Moscow 1972 (In Russian).

SINHA, A. K.: Clay Mineralogy of Green Shale from Krol B Horizon of Solan Area in the Himalaya. — Recent Researches in Geology, vol. 2, p. 64—75, Hindustan Publ. Corp., Delhi 1974.

SINHA, A. K.: The Tectono-Stratigraphic Significance of the Blaini formation of the Simla Hills. — Bull. Ind. Geol. Assoc., Special Blaini volume 8 (2), p. 151—161, Chandigarh 1975 a.

SINHA, A. K.: Calcareous Nannofossils from Simla Hills (Himalaya, India) with a Discussion on their Age in the Tectono-stratigraphic column. — J. Geol. Soc. India, vol. 16, No 1, p. 69—77, Bangalore 1975 b.

SINHA, A. K.: Riphean Stromatolites from Western Lower Himalaya, Himachal Pradesh, India, Fossil Algae. — Editor E. Flügel, p. 86—100, Springer-Verlag Berlin, Heidelberg, 1977 a.

SINHA, A. K.: Geochronology, petrography-petrochemistry and tectonic significance of basic rock suites of North-Western Himalaya — with special reference to Himachal Himalaya, India. — Recent Researches in Geology 3, p. 478—494, Hindustan Publ. Corp. Delhi 1977 b.

SINHA, A. K., & BAGDASARIAN, G. P.: Potassium-Argon dating of some magmatic and metamorphic rocks from Tethyan and Lesser Zones of Kumaun and Garhwal Indian Himalaya: And its implication in the Himalayan Tectogenesis. — Colloqu. Intern. C. N. R. S. No 268, Géologie et Écologie de l'Himalaya, p. 387—394, Paris 1976.

SINHA, A. K., & JHINGRAN, A. G.: Deep Seated Lineament Structures in Himalaya and Caucasus: Their Role in the History of Geological Development and Metallogeny. — Himal. Geol. 7, p. 46—64, Delhi 1977.

SRIKANTIA, S. V., & BHARGAVA, O. N.: The „Jaunsar" Problem in the Himalaya — a Critical Analysis and Elucidation. — J. Ind. Geol. Soc. 15 (2), p. 115—136, Bangalore 1974.

TEWARI, A. P., & MEHDI, S. H.: Geology of Nainital-Almora Himalaya, U. P. (Guide to Excursion).—22th Int. Geol. Congr., 19 pp., New Delhi 1964.

VALDIYA, K. S.: An Outline of the Stratigraphy and Structure of the Southern Part of Pithoragarh District, Uttar Pradesh. — J. Geol. Soc. Ind. 3, p. 27—48, Bangalore 1962.

VALDIYA, K. S.: The Stratigraphy and Structure of the Lohaghat Subdivision, District Almora, U. P. — Quart. J. Geol., Min. and Metallurg. Soc. Ind. 35 (3), p. 167—180, 1963.

VALDIYA, K. S.: Petrography and Sedimentation of the Sedimentary Zone of Southern Pithoragarh, U. P. Himalaya. — Wadia Comm. Vol. Min. and Metallurgical Inst. of India, p. 521—544, 1965.

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

VALDIYA, K. S.: Origin of the magnesite deposits of southern Pithoragarh, Kumaun Himalaya, India. — Econom. Geol. 63, p. 924—934, 1968.
VALDIYA, K. S.: Structural Set-Up of the Kumaun Lesser Himalaya. — Colloqu. Intern. C. N. R. S., No 268, Écologie et Géologie de l'Himalaya, p. 449—462, Paris 1976.
VARADARAJAN, S., & RAWAT, R. S.: Some Aspects of the Amritpur Granite, Nainital District, Kumaon Himalaya. — Himal. Geol. 6, p. 467—484, Delhi 1976.
WADIA, D. N.: The Syntaxis of the North-West Himalaya: Its Rocks, Tectonics and Orogeny. — Rec. G. S. I. 65 (2), p. 189—220, Calcutta 1931.

Manuskript bei der Schriftleitung eingelangt im Juni 1978.

Jahrbuch der Geologischen Bundesanstalt, 121. Band 1978 – Beilage 6
G. FUCHS & A.K. SINHA, – Plate 1

Geological Map of the Lesser Himalaya of Garhwal - Kumaun

From literature and own observations compiled by G. FUCHS, 1978

Alluvium
Siwalik Zone
Subathu - Dagshai
Tal
Carbonate formations (Krol, Shali, Deoban, etc.)
Black Slate formations (Infra Krol, Shali Sl., Sor Sl., etc.)
Fossiliferous Upper Palaeozoics of Lansdowne Syncline

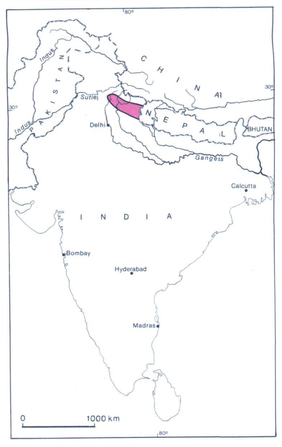
Blaini, Mandhali
Jaunsar: Nagthat, Chandpur
Chail and Nagthat undivided
Chail i.gen.
Chail phyllites, quartzites (e.g. Berinag Qu.)
Basic metavolcanic rocks
Orthogneisses in Chail (Lansdowne, Ramgarh etc.); Amritpur Granite
Limestone near Simla Slate - Chandpur boundary
Simla Slates
Crystalline i.gen.
Dip (horizontal to vertical)
Thrust
Fault

Scale 1:500 000
(for both maps)
0 5 10 15 20 25 30 35 40 km

Tectonic Map

Tertiary Zone (T)
Tertiary formations of Lesser Himalaya
Autochthonous windows
Parautochthonous Unit (P)
Chail Nappes (C1, 2, 3)
Carbonate formations of Chail Nappes (Deoban etc.)
Crystalline Nappes i.gen. (Cr)
Thrust
Fault
Syncline
Anticline
M.B.T. Main Boundary Thrust
M.C.T. Main Central Thrust

Location of the Area shown in Plate 1

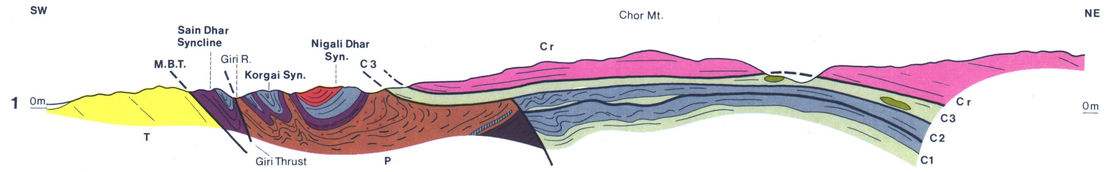


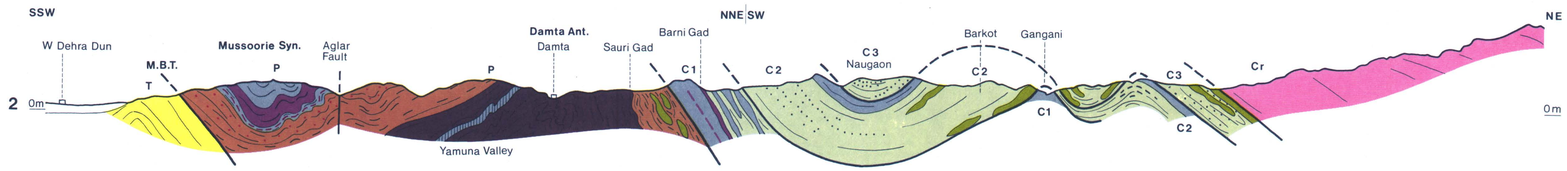
Druck: Kartographische Anstalt Freytag – Berndt und Artaria, Wien
Graphische Gestaltung und Reprotechnik: GEOLOGISCHE BUNDESANSTALT, WIEN
Graphik: Ch. Steinbauer

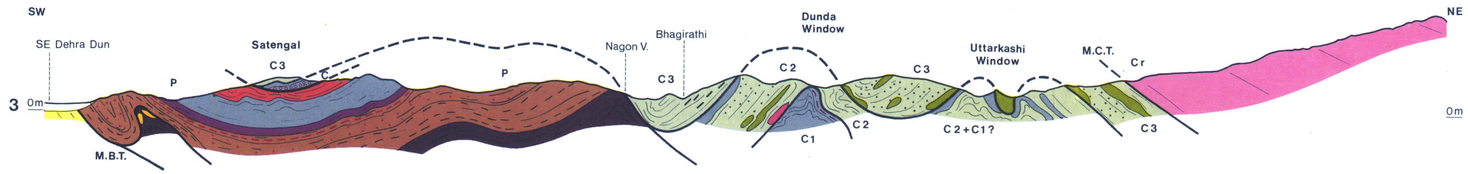
©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

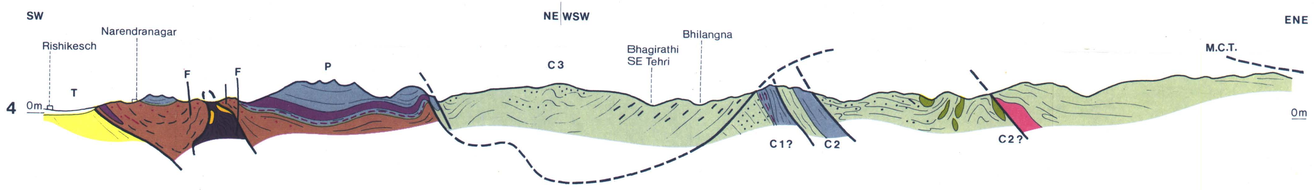
Sections through the Lesser Himalaya of Garhwal-Kumaun

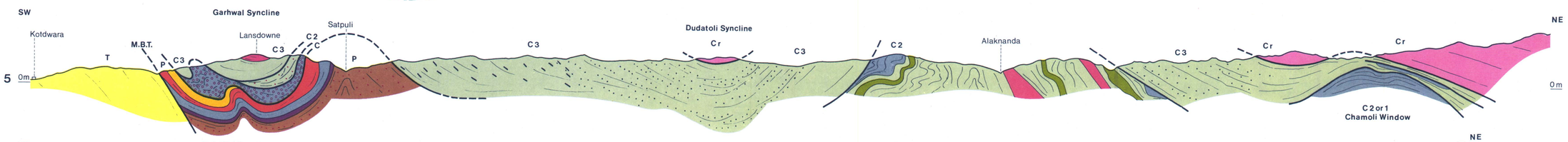
From literature and own observations compiled by G. FUCHS, 1978

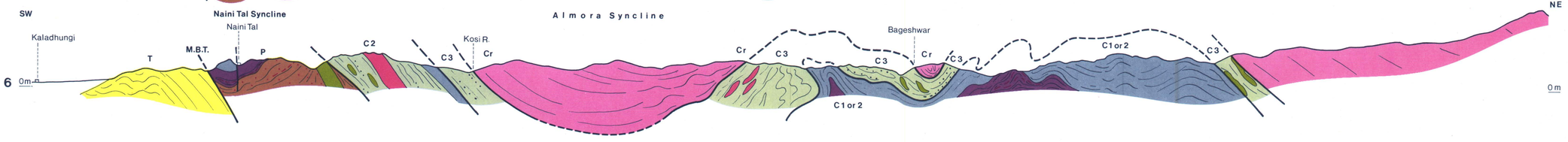


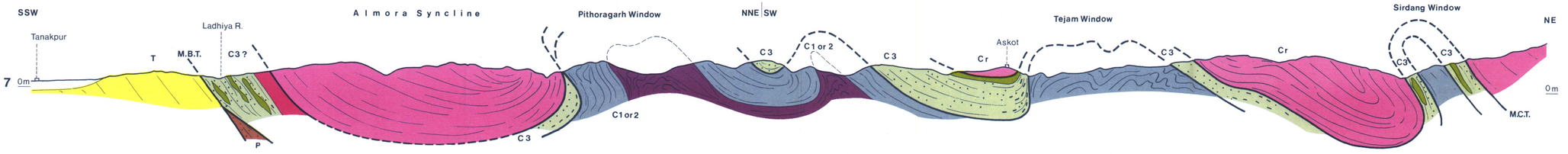












Scale 1 : 200000
(also vertical)

0 5 10 15 20 km

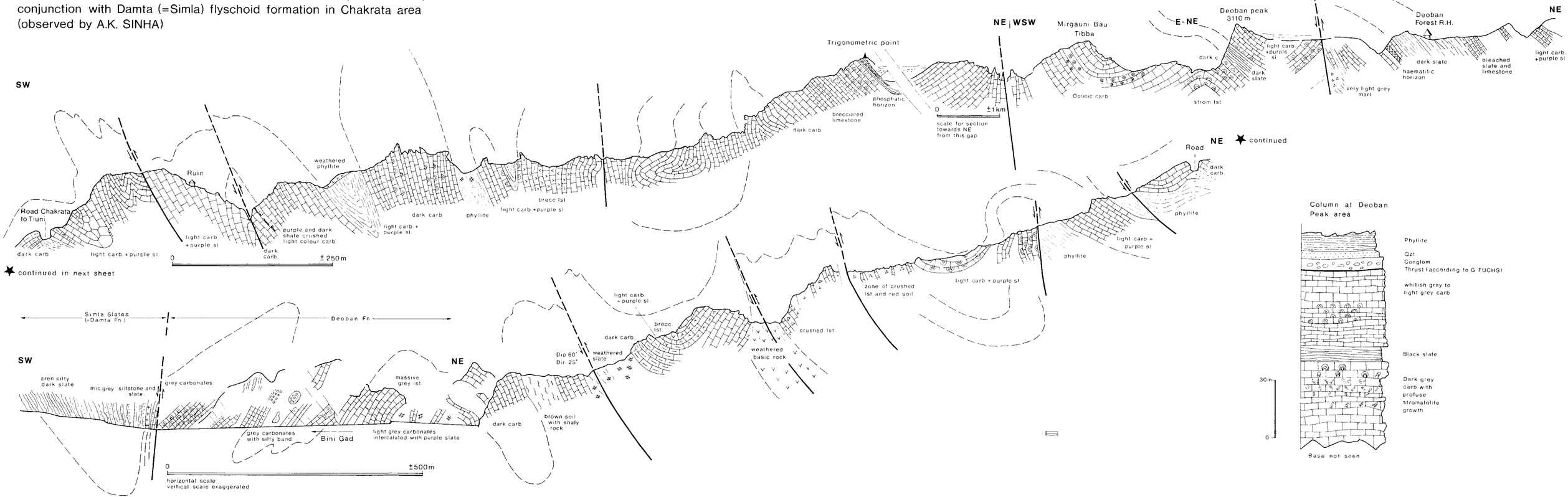
- Alluvium
- Siwalik Zone
- Subathu-Dagshai
- Tal
- Carbonate formations (Krol, Shali, Deoban, etc.)
- Black Slate formations (Infra Krol, Shali Sl., Sor Sl., etc.)
- Fossiliferous Upper Palaeozoics of Lansdowne Syncline
- Blaini, Mandhali
- Nagthat } Jaunsar
- Chandpur }
- Chail and Nagthat undivided
- Chail i.gen.
- Chail phyllites, quartzites (e.g. Berinag Qu.)
- Basic metavolcanic rocks
- Orthogneisses in Chail (Lansdowne, Ramgarh etc.) Amritpur Granite
- Limestone near Simla Slate-Chandpur boundary
- Simla Slates
- Crystalline i.gen.
- Thrust
- Fault

Druck: Kartographische Anstalt Freytag-Berndt und Artaria, Wien

Graphische Gestaltung und Reprotechnik:
GEOLOGISCHE BUNDESANSTALT, WIEN

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

Detailed measured section to depict the deformational style of frontal part of Deoban carbonates in tectonic conjunction with Damta (=Simla) flyschoid formation in Chakrata area
(observed by A.K. SINHA)



ZOBODAT - www.zobodat.at

Zoologisch-Botanische Datenbank/Zoological-Botanical Database

Digitale Literatur/Digital Literature

Zeitschrift/Journal: Jahrbuch der Geologischen Bundesanstalt

Jahr/Year: 1978

Band/Volume: 121

Autor(en)/Author(s): Fuchs Gerhard, Sinha A.K.

Artikel/Article: The Tectonics of the Garhwal-Kumaun Lesser Himalaya 219-241