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Contributions to the Geology of the North-Western Himalayas

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By GERHARD FUCHS

With 64 figures and 5 plates (= Beilage 1—5)

Data up to 1972, except Pl. 1

Schlüsselwörter
NW-Himalaya
Stratigraphie
Tektonik
Fazies

Contents

Zusammenfassung

Es war die Aufgabe der Österreichischen Geologischen Himalaya Expedition 1969, durch gezielte Untersuchungen im NW-Himalaya grundlegenden Fragen der Stratigraphie, Tektonik und Metamorphose, die den gesamten Himalaya betreffen, näher zu kommen.

In Kashmir wurde das Profil durch die Pir Panjal-Kette von Riasi nach Gulabgarh aufgenommen (Pl. 1, Fig. 1—5). Die Kalk-Dolomitvorkommen im Untergrund der Murree-Zone entsprechen den Shalis. An einer Überschiebung folgt über dem Tertiär die Parautochthone Einheit. Sie besteht zunächst aus einer mächtigen Schieferfolge, die lithologisch den Simla Slates entspricht. Darüber folgt, anscheinend ohne scharfe Grenze, der Agglomeratic Slate (Ober-Karbon — Perm) und Panjal-Trap. Nach einer weiteren Überschiebung folgen epimetamorphe Schieferfolgen (Chail-Tanol) mit eingeschalteten Granitgneisintrusionen. In dieser Folge dürfte die Überschiebungsfläche der Kristallin-Decke verborgen sein, da die hangendsten Schiefer bereits dem Kashmir-Synklinorium angehören und allmählich in den Agglomeratic Slate übergehen. Es folgt Panjal-Trap und das Permo-Mesozoikum des Gulabgarh-Passes.

Im Gebiet des Apharwat, S Gulmarg, wurde die lithologische Übereinstimmung von Tanol und Chail, wie in obigem Profil, bestätigt und die stratigraphische Stellung zwischen Dogra Slate und Agglomeratic Slate festgestellt.

Die Untersuchungen im Kolahoi-Basmai-Gebiet, im Liddar-Tal und SE-Kashmir zeigen, daß Chail-Tanol und Muth Quarzit (Devon) einander weitgehend altersmäßig entsprechen – der stratigraphische Umfang der Tanols kann jedoch mindestens vom Ordoviz bis ins Ober-Karbon reichen (z. B. in SW-Kashmir).

Das Profil über den Marbal Paß nach Kishtwar stellt die Verbindung her mit der Geologie des südöstlich an Kashmir anschließenden Gebietes von Chamba-Pangi (Pl. 4). Man quert die paläozoische Schichtfolge Kashmirs Zewan-Serie, Panjal-Trap, Agglomeratic Slate, Fenestella Shales, Syringothyris Limestone, Tanol, Dogra Slate gegen das Liegende zu und gelangt allmählich ins Kristallin. Dieses besteht aus Glimmerschiefern, Para-, Misch- und Orthogneisen, die Granat und Disthen führen. Darunter gelangt man im tief eingeschnittenen Chenab-Tal in das Fenster von Kishtwar, welches bei dieser Querung entdeckt wurde. Epimetamorphe Quarzite, Phyllite und Grüngesteine der Chail-Decke stehen hier an. An einem jungen Bruch grenzen diese Gesteine an das hochgradig metamorphe Kristallin des Rahmens.

Das Chenab (Chandra)-Tal aufwärts stehen Chails und ausgedehnte Intrusivkörper von Metagranit an. Bei Atholi, am östlichen Fensterrand, gelangt man in die typischen dunklen Phyllite

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und Glimmerschiefer und lichten Quarzite der Unteren Kristallin-Decke. Darüber folgt der mächtige Mischgneiskomplex der Oberen Kristallin-Decke. Wie in Nepal, so läßt sich auch hier feststellen, daß die grobschuppig flaserigen Granat-Disthengneise (± Staurolith) und Augengneise älter sind als die fein- bis mittelkörnigen Mischgneise.

Das Sach-Paß-Profil von Kilar im Chandra-Tal bis Dalhousie quert ein weites Synklinorium vergleichbar dem von Kashmir (Pl. 1, 4, Fig. 3, 36, 43): Das Chandra-Tal gegen Südosten verlassend, wird die Metamorphose immer schwächer, und man steigt in die Sedimenthülle der Oberen Kristallin-Decke auf, in Dogra Slates, Tanols, Syringothyris-Kalk, der mit Tanols verzahnt ist, Fenestella-Schiefer und Agglomeratic Slate. Letzterer bildet den Kern der Sach-Paß-Mulde (Fig. 36). Im Südwestflügel derselben folgen unter dem Agglomeratic Slate unmittelbar die Tanols, darunter Dogra Slates. Syringothyris-Kalk und Fenestella-Schiefer keilen somit gegen Südwesten zu aus und werden durch Tanols faziell vertreten. Es zeigt sich somit in Chamba ähnliche Faziesverteilung wie in Kashmir. Nach einer weiten Aufwölbungszone, bestehend aus Dogra-Schiefern und Tanols, folgt in der Kalhel-Mulde Panjal Trap, Agglomeratic Slate, Gondwanas (?), Zewan-Formation und Karbonatgesteine und Quarzite der Trias. Die konglomeratischen Schiefer des Agglomeratic Slate sind höchstwahrscheinlich Tillite der permischen Vereisung.

Im Südwestflügel der Kalhel-Mulde werden die typischen Tanol-Schiefer durch eine dunkle Schieferfolge vertreten. Im Liegenden derselben folgen Simla-(Dogra-)Schiefer.

S von Chamba heben die Simla-Schiefer an einer Überschiebung steil über Chails und Metagraniten aus. Damit gelangt man in die unterlagernde Chail-Decke. Wie schon in der Pir Panjal-Kette beobachtet, fehlt das mächtige Hochkristallin, das die Basis der Kristallin-Decke sonst bildet in den Randketten im Südwesten (Fig. 3).

Die Parautochthone Einheit tritt im Südwesthang der Dhauladhar-Kette zwischen Chail-Decke und Tertiär-Zone als schmales Band von Simla-Schiefern und ihnen eingeschalteten Kalken auf.

Eine Exkursion durch Hazara (Pakistan) erbrachte neue Ergebnisse, die jedoch noch Widersprüche enthalten. Um Abbottabad finden wir die Schichtfolge des Niederen Himalaya: Hazara-(Simla-) Schiefer, darüber transgredierend den Tanakki-(Blaini-)Tillit, der über rote Sandsteine und Schiefer in eine mächtige Karbonatfolge überleitet (Sirban), die den Shalis entspricht. In der darüber transgredierenden Hazira-Formation fanden wir Fossilien (Poriferen), die nach Mostler (Fuchs & Mostler, 1972) für kambrisches Alter sprechen und somit ein früh oder vorkambrisches Alter der unterlagernden Schichten belegen. Anderseits finden wir aber in der Tanol-Zone die Folge: Simla-Schiefer, Tanol, Tanakki-Tillit, rote Quarzite und Schiefer, Sirban Dolomit, wobei die Tanols mit krinoidenführenden Karbonatgesteinen verzahnt sind (bei Tarbela), deren silurisch-devonisches Alter westlich des Indus eindeutig bestimmt werden konnte (Stauffer, 1968). Dies spricht für mittel- bis höherpaläozoisches Alter der Tanakki-Sirban Schichtfolge.

Im Gebiet Swabi-Nowshera konnte die enge stratigraphische Bindung von Tanols (Chails) und silurisch-devonischen Karbonatserien immer wieder festgestellt werden, was im Einklang mit den Beobachtungen aus Kashmir und Chamba steht.

Das Altersproblem der Schichtfolge des Niederen Himalaya (paläozoisch oder präkambrisch) ist somit ungelöst, doch werden eine Reihe neuer Beobachtungen angeführt und in einer umfassenden Diskussion des Problems erörtert.

Gerade im NW-Himalaya kann durch bestehende Faziesverzahnungen klar gezeigt werden, daß die verschiedenen geologischen Zonen dieses Raumes seit jeher eng benachbart waren. Die Tibetische Fazies greift im höheren Mesozoikum nach Süden bis Hazara über, anderseits reicht der Einfluß der Gondwana-Fazies im Jung-Paläozoikum nach Norden bis in die Tibetische Zone. Der Raum zwischen dem Indischen Schild und dem Transhimalaya hat zwar eine Einengung in der Größenordnung von 500 km erfahren (Gansser, 1966), doch ist eine Drift des Indischen Subkontinents über tausende von Kilometern, wie sie von Kanwar (1972) angenommen wird, auszuschließen.

Die Metamorphose betreffend, werden Argumente beigebracht, daß das Kristallin polymetamorph ist.

Die tektonischen Großeinheiten lassen sich von Nepal durch den NW-Himalaya bis Hazara durchverfolgen, sind aber in den verschiedenen Abschnitten stärker oder schwächer entwickelt. Es ist interessant, daß in Kashmir und Chamba das Hochkristallin der Kristallin-Decke gegen Südwesten zu auskeilt. Dadurch kommen die hangenden Sedimentserien mit der unterlagernden Chail-Decke in Berührung. Es ist eine oft gemachte Beobachtung, daß in einer Decke die höheren Schichtglieder vorauseilen, die Basisschichten aber infolge Reibung zurückbleiben.

Schließlich wird betont, daß der NW-Himalaya durch seine Faziesverzahnungen — die Folge komplizierter paläogeographischer Verhältnisse — eine besondere Bedeutung hat bei der Behandlung der stratigraphischen und tektonischen Probleme des Himalaya. Die hier gewonnenen Erkenntnisse sind dabei zu berücksichtigen.

Abstract

The aim of the Austrian Geological Himalayan Expedition 1969 was to study certain areas in the NW-Himalayas to elucidate general problems of all-Himalayan stratigraphy, tectonics and metamorphism.

The Riasi-Gulabgarh section crosses the Pir Panjal Range of Kashmir: The carbonate rocks, forming the base of the Murree Zone, correspond with the Shali Formation. The Parautochthonous Unit overlies the Murrees (Lower Miocene) on a thrust plane. It consists of a thick pile of slates, resembling Simla Slates, which seem to pass upwards into the Agglomeratic Slate (U. Carb.-Permian) — with the Panjal Trap above. Epimetamorphic phyllites and schists follow on a higher thrust plane. These Chail-Tanol rocks are intruded by granite-gneiss. The thrust plane of the Crystalline Nappe seems to be hidden in this thick succession as the highest Tanols (Chails) grade upwards into the Agglomeratic Slate of the Kashmir Synclinorium. Panjal Trap and the Permo-Mesozoic sequence of the Gulabgarh Pass form the top.

As in the section described above, the lithological resemblance of Tanols and Chails was found in the Apharwat area (S of Gulmarg). Their stratigraphic position between the Dogra Slates and the Agglomeratic Slate is well established.

Explorations in the Kolahoi-Basmai area, the Liddar valley, and SE-Kashmir revealed the correlation of Tanol and Muth Quartzite (Devonian). The Tanols, however, may range from at least Ordovician to the Upper Carboniferous, e. g. in the SW.

The Marbal Pass section from Kashmir to Kishtwar relates the geology of Pangi-Chamba with that of Kashmir (Pl. 4). It crosses the Palaeozoic succession of Kashmir from the Zewan Formation through Panjal Trap, Agglomeratic Slate, Fenestella Shales, Syringothyris Limestone, Tanols, down into Dogra Slates, which pass into the underlying metamorphic complex. This consists of mica schists, paragneiss, migmatites, and orthogneiss. Garnet and kyanite are frequent in these rocks. The Kishtwar Window, which was discovered by the author, shows epimetamorphic quartzites, phyllites, and basic rocks of the Chail Nappe underlying the described gneisses. The Chails outcrop along the Chenab (Chandra) valley up to Atholi, and are intruded by extensive masses of metagranite. Along the eastern border of the tectonic window we find the typical dark coloured phyllites and mica schists, and quarzites of the Lower Crystalline Nappe. The thick migmatite series of the Upper Crystalline Nappe follows above. My observations there indicated that just as in Nepal, the flasery garnet-kyanite gneisses (± staurolite) and augen gneisses are older than the fine-to medium grained migmatites.

The Sach Pass traverse from Kilar in the Chandra valley to Dalhousie crosses the Chamba Synclinorium, which corresponds with that of Kashmir (Pl. 1, 4, Fig. 3, 36, 43). SW of the Chandra valley, the metamorphism becomes low-grade, and ascending we cross the sequence of the sedimentary cover of the Upper Crystalline Nappe: Dogra Slates, Tanols, Syringothyris Limestone, Fenestella Shales, and Agglomeratic Slate. The last forms the core of the Sach Pass Syncline. The Syringothyris Limestone is interbedded with the highest Tanols in the NE-limb of that syncline, whereas Syringothyris Limestone and Fenestella Shales are missing in the SW-flank. They are replaced by Tanols towards SW, where these grade into the Agglomeratic Slate, which resembles the facies distribution in Kashmir. After a wide anticline, consisting of Dogra Slates and Tanols, we cross the Kalhel Syncline. It is formed by Panjal Trap, Agglo-

meratic Slate, Gondwanas (?), Zewan Formation, and Triassic carbonate rocks and quartzites. The pebbly mudstones of the Agglomeratic Slate most probably represent tillites of the Permian glaciation. The Tanols of the SW-flank of the Kalhel Syncline are replaced by a dark slate series, with Simla (Dogra) Slates below. Under them we cross a thrust plane, and get into Chails and metagranites of the Chail Nappe S of Chamba. As in the Pir Panjal Range the high grade metamorphic series of the Crystalline Nappe are missing in the south-western parts of that unit (Pl. 1, Fig. 3). The Parautochthonous Unit is represented by a narrow band of Simla Slates and intercalated limestones. It lies under the Chail Nappe and is thrust onto the Tertiary series.

The observations on my excursion to Hazara (Pakistan) are contradictory. The sequence of the Lower Himalayas is found in the Abbottabad area: Hazara (Simla) Slates, Tanakki (Blaini) Tillite transgressing after a gap, then red sandstones and shales, grading upwards into the thick carbonates of the Sirban (Shali) Formation. The Hazira Formation, following after a gap, yielded fossils (porifera) which according to Mostler (Fuchs & Mostler, 1972) indicate Cambrian age, which means that the underlying succession is early or pre-Cambrian. The Tanol Zone, on the other hand, shows the sequence: Hazara Slates, Tanols, Tanakki Tillite transgressing on Tanols, red quartzites and slates, and Sirban Dolomite. The Tanols are interbedded with crinoid bearing carbonate beds at Tarbela, the age of which has been established Siluro-Devonian W of the Indus (Stauffer, 1968). These observations suggest a Middle to Upper Palaeozoic age of the Tanakki-Sirban succession.

The close stratigraphic relation of the Siluro-Devonian carbonate formation with the Tanols is well-established in the Swabi-Nowshera region.

Thus the problem whether the sequence of the Lower Himalayas is Precambrian or Palaeozoic still awaits solution, and several new arguments are brought into the discussion.

The facies intertonguings of the NW-Himalayas clearly show that the various zones throughout the geological history were close to the Indian Subcontinent. In the Upper Palaeozoic the Gondwana facies, for instance, has reached Kashmir and even as far as the Tibetan Zone of Spiti. On the other hand, typical Mesozoic series of the Tethys transgress on the Lower Himalayan succession in Hazara. Thus there is no room for the hypothesis still held by Kanwar (1972) that the Indian Subcontinent has drifted for thousands of kilometers towards the Tethys.

Concerning the metamorphism of the Himalayan Crystalline my observations suggest polymetamorphism.

The main tectonic units can be traced throughout the NW-Himalayas from Nepal to Hazara.

Preface

The paper resulted from the studies carried out by the author in the course of the Austrian Geological Himalayan Expedition 1969.

The expedition was sponsored by the "Fonds zur Förderung der wissenschaftlichen Forschung", the "Bundesministerium für Unterricht", the "Kulturamt der Stadt Wien", the "Österreichische Akademie der Wissenschaften", the "Österreichische Alpenverein", and other official and private institutions. The author wants to express his deep gratitude to all of them for having made this research possible.

He is also very much indebted to Hofrat Dr. A. Ruttner, director of the Geological Survey, for his great assistance in every respect and for granting special leave to carry out these studies.

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Introduction

The Alps, after a century of careful geological studies, still offer a series of unsolved problems, even though the whole mountain range has been mapped, at least roughly, and many areas have been subject to repeated and intricate investigation.

If we consider the difficulties of research in the Himalayas, it is not surprising that there are many open questions in Himalayan geology. First there are the difficulties of access and transport; scientific work in high altitudes and under expedition conditions needs considerable physical strength and mental qualities. Geologists from abroad have to afford a large amount of money for their work. Indian geologists on the other hand are not able to visit essential areas in the Pakistan Himalayas such as Hazara, and Pakistanis can not study the classical localities in India. For political reasons many parts of the Himalayas are restricted areas, thus still huge gaps in our knowledge will remain.

In the course of his 1969 expedition the author has visited several areas in the Indian and Pakistan Himalayas. From literature and personal experience such regions were selected for investigation which seemed particularly favourable to solve certain intricate problems. The observations and conclusions are presented in this paper.

There are two main problems in Himalayan geology:

1. The age of the unfossiliferous sequence of the Lower Himalayas and

2. The age of the metamorphic events in the Crystalline of the axial zone.

1. The axial crystalline zone separates the Tibetan or Tethys Zone abounding in fossils from the units of the Lower Himalayas with their sedimentary sequences almost devoid in fossils. This contrast has been explained by assuming a Precambrian age of the unfossiliferous series or by reconstructing two different basins of deposition. Views and arguments of various workers are discussed in Fuchs & Frank (1970, p. 56—63, and Fuchs, 1971, p. 207—208). In the NW-Himalayas, in Kashmir, Chamba, and Hazara we find fossiliferous beds from the Tethys together with formations typical for the Lower Himalayas. There are also strong influences from the Gondwana continent. This intermingling of various facies makes it possible to come nearer to the solution of the age problem of the Lower Himalayan sequence.

2. First the metamorphic complex of the axial zone was thought to be Precambrian a view held also by some modern workers (Pilgrim & West, 1928; Saxena & Pande, 1968, and others).
1967 we have given reasons for Caledonian metamorphism admitting the presence of older and younger metamorphic events (p. 151). Recently Frank has advanced the view that the Crystalline is the product of Alpine metamorphism (in Fuchs & Frank, 1970, p. 62). In the course of our expeditions we have found identical metamorphic rock assemblages in various parts of the Himalayas. Thus the physical age determinations given by Prof. Dr. E. Jäger from the samples, which my co-worker Frank has taken in the NW-Himalayas, seem to be valid for the Crystalline Zone from Kashmir to Nepal.

Furthermore, a series of new tectonic data were found in the course of our 1969 investigations. Again, the main structural units proved to be traceable over enormous distances. However, there are features unique to certain regions.

The author holds the view that, in the present state of exploration, it is still necessary to fully describe, as far as possible, the routes made. The reader not working in the Himalayas who finds this tedious is referred to reviews and summarizing chapters.

1. Descriptive Part

1.1. Kashmir (Fig. 1)

Connected with the Plains by the Banihal road, Kashmir is one of the Himalayan regions easiest to access. It has a tradition in tourism and thus provides good facilities for scientific work. Therefore, Kashmir is one of the geologically best-studied regions of the Himalayas. In particular the fossiliferous sequence of the Kashmir Synclinorium has been subject to extensive studies; but this is not so the lower tectonic units which are confined to the SW-slope of the Pir Panjal Range. We started work in that structurally complicated area.

1.1.1. The Riasi-Gulabgarh Pass Section (Pl. 1, Fig. 1—5)

The section crosses all tectonic units from the Siwalik foothills up to the Palaeo — and Mesozoic sequence of the Kashmir Basin. Observations along the Banihal road are found in LYDEKKER (1876), WADIA (1931), PASCOE (1959), RAINA & KAPOOR (1964), FUCHS (1967), and TEWARI & SINGH (1967). On the section to be described, which is W of the Banihal road, a few data may be obtained from WADIA (1928, 1931 and 1937).

Riasi at the river Chenab is situated in the Siwalik Zone (Fig. 4). The higher mountains N and E of the village are formed by the Sirban or Jammu Limestone formerly known as "Great Limestone". This carbonate complex in which dolomite is predominant is thrust onto the Siwaliks along the steep NNE dipping Main Boundary Thrust. This tectonic line separates the Siwalik from the Murree Zone (WADIA) in the N.

The unfossiliferous carbonate rocks form a generally well-bedded sequence of light grey to bluish dolomites and limestones. Many forms of stromatolites, intraformational breccias, oolites, fine laminations and lenticular arenaceous layers occur. Chert is very common in these rocks. There are also arenaceous and quartzitic beds. In the lower part of the NNE dipping series there are intercalations of dark marls, shales, or slates.

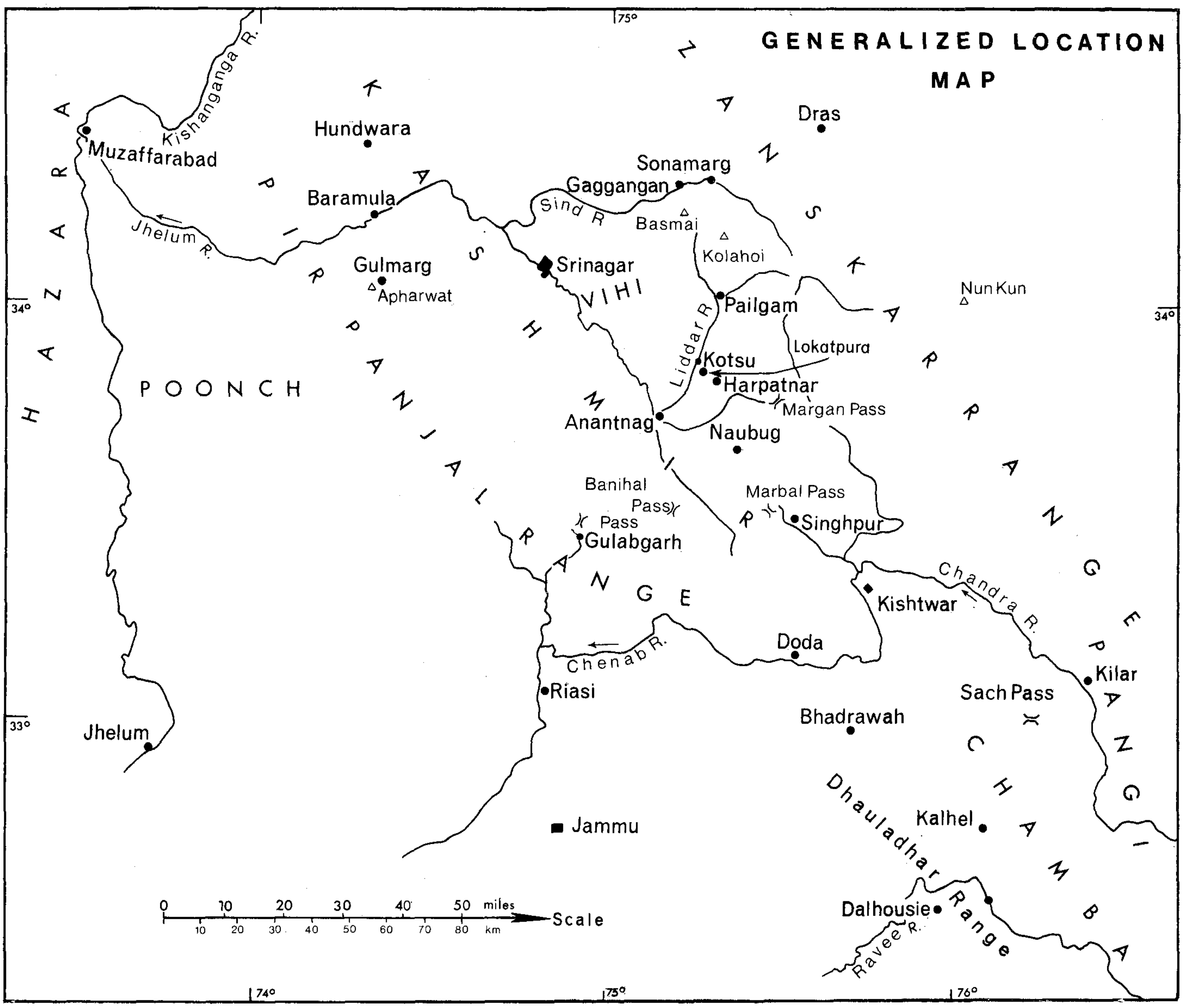

Fig. 1. Generalized location map of Kashmir, Pangi and Chamba.

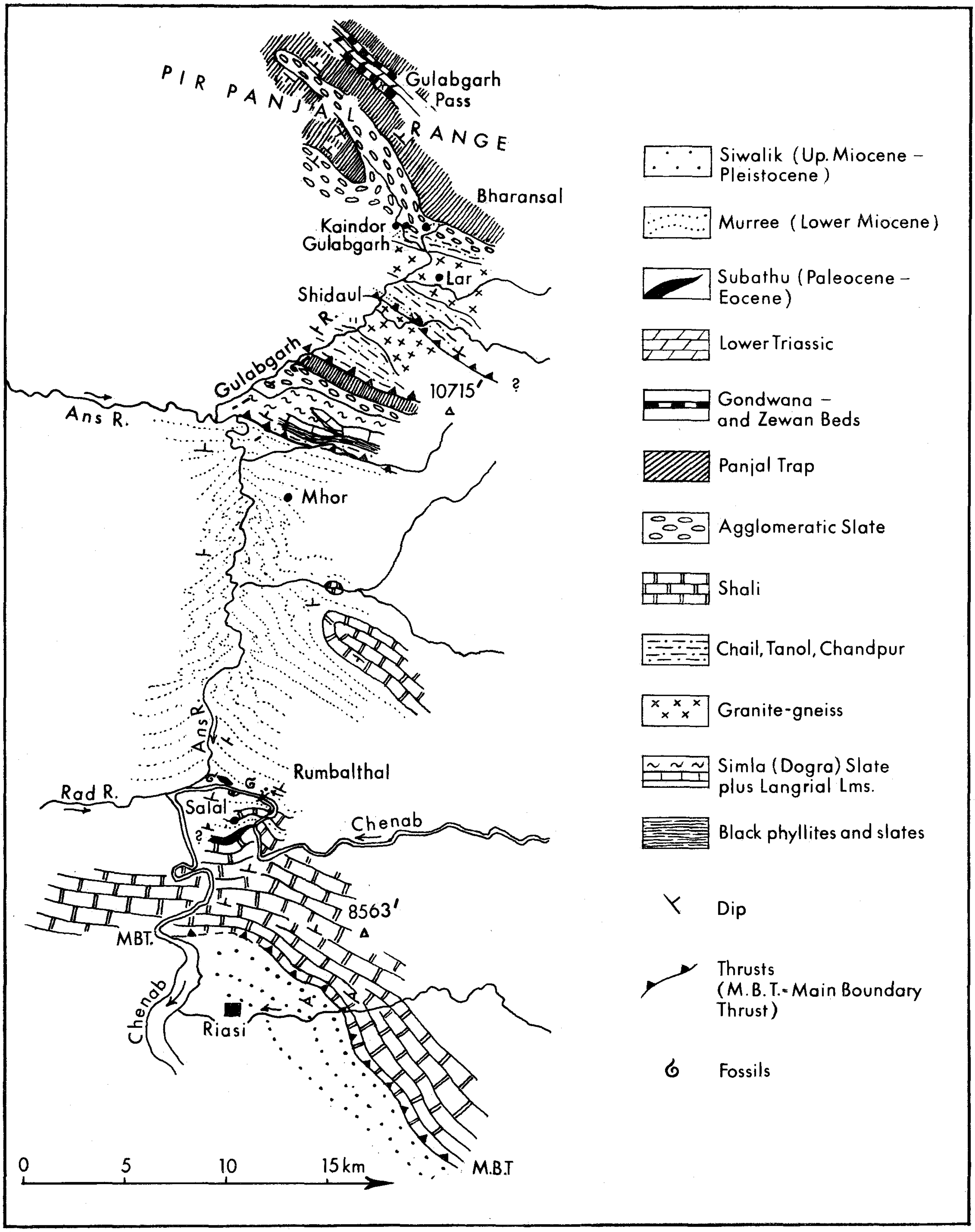

Fig. 2. Scetch map along the Riasi — Gulabgarh section.

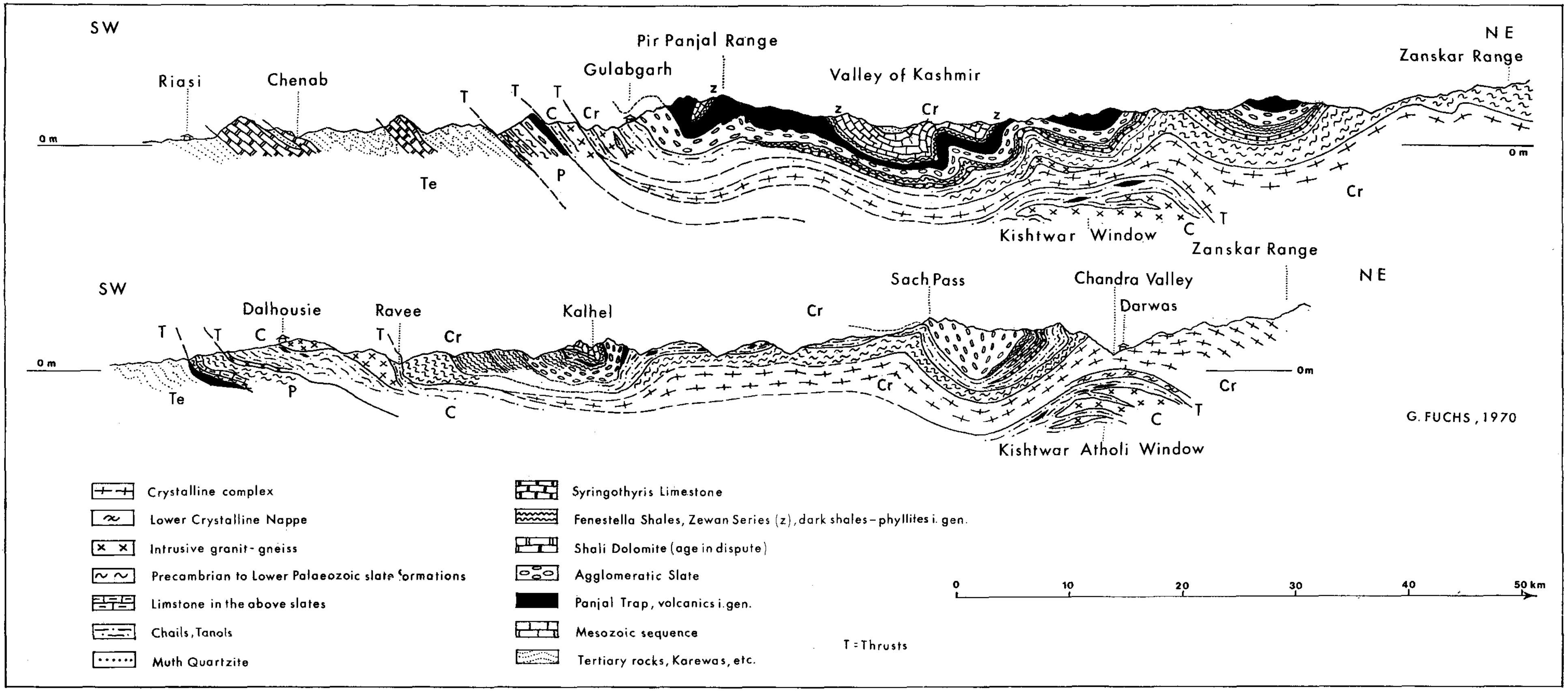

Fig. 3. Sections across Kashmir and Chamba.

Te	Tertiary Zone	C	Chail Nappe
P	Parautochthonous Unit	Cr	Crystalline Nappe

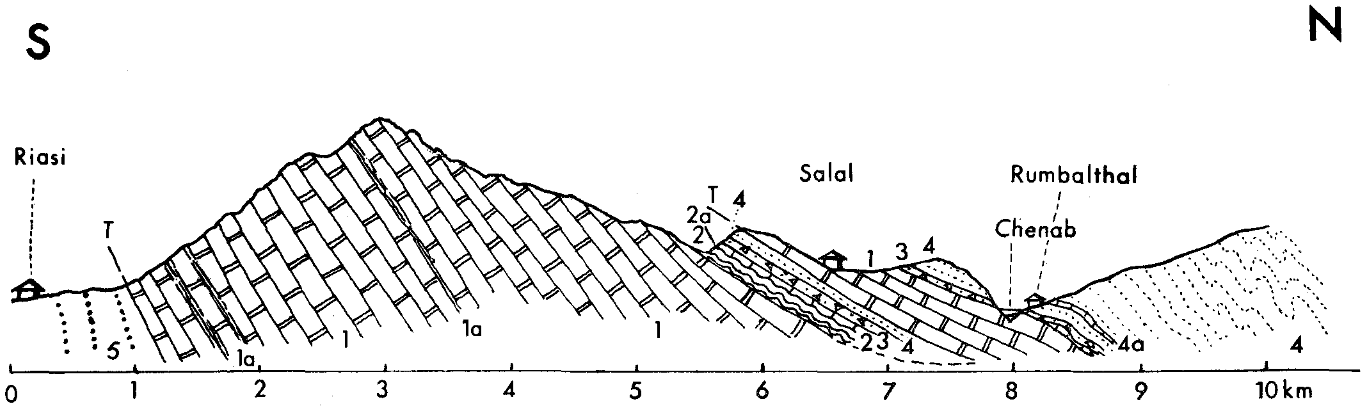

Fig. 4. The Riasi section, Jammu.

1 Shali
1 a Black slates (Shali Slates)
2 Siliceous shales passing into
2 a Limestone
3 Breccia and white quartzite
4 Murrees
4 a Limestone layers
5 Siwaliks
T Thrust

Purple layers have been observed in one locality only. The thickness of this shallow-water sequence is estimated at 1000 to 2000 m.

The lithological identity with the Shalis in the E and the corresponding carbonate rocks of Hazara in the W is obvious. Sirban-, Jammu-, and Shali Limestone are regarded synonymous and we use the last name which is common in the Punjab-Kumaon—, and Nepal Himalayas. WADIA (1937) from a more western occurrence describes an interbedding of the carbonate rocks with black slaty tuffs which he correlates with similar beds of the Agglomeratic Slates. This would prove a Permo-Carboniferous age of the unfossiliferous carbonate rocks. From our traverse at Riasi we found no indication of age.

The carbonate rocks are generally overlain by Eocene beds and a thick pile of Murrees (L. Miocene). N of the Riasi range near the village Salal the contact to overlying beds of uncertain age is exposed along the road:

The topmost 20 cm of the dolomite show a change in colour from grey to reddish and cream. Siliceous shales follow with a sharp formational boundary. They are thin-bedded (3—20 cm), partly laminated and of khaki, brown, green, and reddish colours; the tints, however, are not like those of the Nagthats or Blainis. The s-planes are somewhat undulating and nodular. There are also layers of pure light grey flint and chert, chert breccias, and limestone.

After 20 m the sequence becomes chocolate coloured, brick red and grey banded.

About 40 m above the top of the dolomite the cabonate content of the series increases. We find thick beds of grey limestone with intercalated shales. Soon the outcrops end.

No fossils were found. However from lithology, the sequence overlying the dolomite could represent Eocene (compare WADIA, 1928, p. 261—264).

Ill-exposed b r e c c i a s follow. Angular pieces (up to 15 cm) of quartzite, chert, siliceous rocks, and red and green shales are embedded in a red matrix. This indicates reworking of the underlying beds.

Again Shali Dolomite follows due to imbrication (see Fig. 4). It is succeeded by white massive brecciaceous quartzite alternating with the described red breccia. The siliceous shales have not been observed.

Red and green micaceous sandstones with intercalated red micaceous shales follow. They form the ridge before the road goes down to the bridge across the Chenab (at Rumbalthal). Due to topography Shali Dolomite, and the quartzites and breccias are also exposed at the banks of the deep cut river (Fig. 4).

The sandstone-shale alternation follows N of the bridge containing a few beds of blue yellow weathering limestones which show indeterminable shell remains of bivalves. These beds may be correlated to similar ones in the Lower Murrees described by WADIA (1928, p. 192—268).

Grey shales, blue lumachelle- and nummulitic limestones and grey calcareous sandstones outcrop E of the junction of the Ans and Chenab rivers. These beds definitely are Subathus (U. Paleocene — Eocene).

The varicoloured sandstone-shale succession shows the typical lithology of the Murrees. The red breccias and white quartzites at their base seem to mark the begin of the Murree sedimentation. They directly overlie the Shali Dolomite or Eocene beds.

For about 18 km only Murrees are exposed along the trail which follows up the Ans river. They are much folded and dip NNE at varying angles. There is one inlier of Shali Dolomite ca. 6 km SSE from the village Mhor. It forms the core of an anticline. Surrounded by the Tertiary rocks the dolomite was easily identified by binocular and discovery of boulders in the river.

The characteristic lithology of the Murrees is an alternation of thick-bedded (1—5 m) sandstone and shale. The green to grey sandstone is micaceous and some beds are glauconitic. It is medium-grained massive, rarely cross-bedded with ripple marks. Triangular marks on s have also been observed. Burrows and clay gall breccias are common. Patches of carbonate weathering in holes have been observed locally. They are the product of syngenetic disruption of carbonate laminae in the sandstone. The red and purple micaceous shales are crumbling when weathered.

The unfossiliferous succession appears to be of fresh water origin. Its lithology corresponds with that of the Dagshais. Both formations are of about same age — Miocene (see Lex. Strat., 1956).

The trail leaves the Murree Zone about 3 km NNE of Mhor (Fig. 2, 3, 5). A small river coming from the E and the W-E course of the Ans river follow a major thrust line (Murree Thrust, WADIA). Along this thrust the Murrees dip beneath a nearly non-metamorphosed succession of Precambrian to Upper Palaeozoic formations. WADIA (1928) called this zone the Autochthonous Fold Belt. He reports occurrences of fossili-

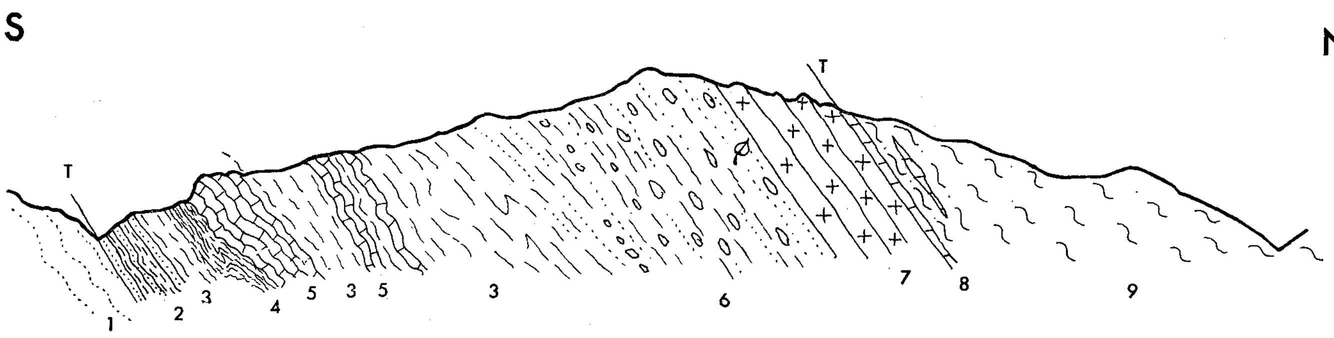

Fig. 5. Section across the Parautochthonous Unit in the Riasi — Gulabgarh traverse (Fig. 2, 3)
1 Murrees
2 Light green, grey slates and green, white quartzites (Chandpur)
3 Simla Slates
4 Black Slates
5 Langrial Limestone
6 Agglomeratic Slate
7 Panjal Trap
8 Schistose carbonate rocks
9 Chails
leaf = Plant microfossils
T Thrusts
Length of the section ca. 6 km.

ferous Eocene rocks and assigns a thick pile of beds to the Eocene, a view we can not follow.

The overthrust unit commences with 80—100 m of light green, grey, or liver coloured slates. The mm— to cm—lamination is caused by arenaceous to silty laminae. Layers of thick-bedded, greenish or white quarzite are intercalated. The lithology resembles that of the Chandpurs. Lineations dip NNE.

Dark grey then black, bleaching slates lie above. They contain rare layers of grey, coarse-grained quartzite. The series attains a tickness of ca. 100 m; due to the disturbance near the Murree Thrust these thicknesses are not the original ones.

Then 50—200 m of grey to blue limestone follow. The rocks are thin-bedded (dm) and frequently exhibit fine lamination (mm). Nodular s-planes are characteristic and lenticular structures are common. The limestone develops from the slates and the limestone itself is an alternation of limestone and dark grey — green slate. The rocks are devoid of fossils.

A slate complex ca. 400 m thick overlies the limestone. In the lower part it contains a few zones rich in limestone. The slates are grey to green and finely laminated, reminiscent of Simla Slates.

At the top the succession becomes silty and arenaceous seeming to grade into a 700 m sequence of slates, greywackes, sandstones, quartzitic sandstones, breccias, and conglomerates. The upper 400 m of this series represent typical Agglomeratic Slate. A sample from the upper part has yielded Permo-Carboniferous spores and plant remains (palynological examination by Prof. Dr. W. Klaus, Univ. of Vienna and Dr. I. Draxler, Geologische Bundesanstalt Vienna).

As to lithology it is characteristic that the coarse-grained layers and slates are not sharply separated. Angular or rounded pebbles and boulders of sizes up to 2 dm may be embedded in green to grey slate, siltstone, sandstone, or greywacke. The components consist of green, grey, and white quartzite, carbonate rock, slate, leucogranite, and normal granite. Towards the top conglomeratic sandstones and grits contain coaly matter and boulders from the formation itself, which points to reworking.

Panjal Trap lies above in a thickness of ca. 400 m. It is fine-grained, partly porphyritic and rather homogeneous. Amygdales are common. A thrust at the top of the Panjal Trap demarcates the Autochthonous Fold Belt from a higher unit.

The sequence Agglomeratic Slate-Panjal Trap represents a normal succession of Permo-Carboniferous age. The lower part of the sequence of the Autochthonous Fold Belt is rather doubtful. Wadia (1928, p. 257—261) was able to prove the existence of Eocene rocks in that zone and he considered all the slates and related limestones to be Eocene (see his sections, Pl. 9, 10). Langrial Limestone (Latif, 1970) which forms part of the Hazara Slates of Hazara exactly resembles that of the limestone here described. Similar calcareous beds are also found in the Attock Slates at Attock, in Simla Slates at the Dalhousie road, or at Naldera and Kakarhatti in the Simla area.

Furthermore there appears to be an upward gradation from the slates into the Agglomeratic Slate in our section; a similar passage has been observed in Chamba (see 1.2.2.). Thus I question the Eocene age of the whole sequence below the Agglomeratic Slate. I point to the possibility that Eocene rocks are tectonically intercalated in a Proterozoic-Palaeozoic succession. Anyhow, we were not able to find any indication of Eocene beds.

The top of the Panjal Trap is marked by a thrust. Besides disturbance there is a break in metamorphism: The nearly non-metamorphic sequence is overlain by altered rocks (greenschist facies).

First comes about 15 m of bluish grey or light schistose limestone. Then a sequence of sericite- and sericite-chlorite phyllite follows, 700 to 800 m thick. In the lower part there are still a few carbonate layers of light crystalline limestone or ferruginous dolomite. The phyllites are green, grey, silvery rocks. The shiny s-planes are partly wavy and crumpled. There are rare quartzites, chlorite phyllites, metadiabases, and graphitic phyllites. The series resembles the argillaceous facies of the Chails.

About 800 m above the base the series becomes more grey and partly laminated, metablastesis increases. Gneisses rich in muscovite and chlorite, showing also some biotite on s, contain some lenticles of feldspar-quartz. They are a link in the passage from the phyllites to the phyllonitic augen gneiss. The feldspar augen (0.3—1 cm) are close and the rock soon becomes a rather homogeneous granite-gneiss. The rock contains basic fishes and is penetrated by dikes of pegmatite, aplite, and quartz. There are layers of cm—thickness which are impregnated with tourmaline. Schistosity and lineation are pronounced.

The granite-gneiss may attain a thickness of ca. 100 m. Frequently its central and upper portions are porphyritic. In the coarse-grained matrix idiomorphic phenocrysts of microcline show lengths up to 3 cm. In the upper part dikes of diabase (0.10—1.50 m) penetrate the granite-gneiss.

Towards the upper boundary of the granite-gneiss there are intercalations of fine-grained muscovite-chlorite-biotite gneiss or schist. At the river near the village Shidaul we leave the granite-gneiss.

Overlying there is a succession of Chail-type rocks: grey, green, silvery sericite phyllites, partly laminated. There are also massive arenaceous beds and coarse-grained (3—5 mm) psammite schists.

Ascending the ridge N of Shidaul this series becomes intruded by granitic and granodioritic rocks. Blocks of the igneous rocks have been noticed in great number already in the river at Shidaul. There are massive metagranites, medium-to coarse-grained with phenocrysts up to 5 cm, amphibol granites and — granodiorites. Smooth-shaped and angular, partly corroded inclusions of the country rock are not infrequent. There are two generations, the older coarse-grained granitic- to granodioritic rocks, and fine-to medium-grained granites which are somewhat younger. Compared with the lower augen granite-gneiss (S of Shidaul) this higher igneous complex appears less disturbed and therefore more massive with preserved intrusive contacts. This may mean a difference in age or of tectonic position.

It is very probable that some of the granites correspond to the Caledonian granites of the Chail Formation (Mandi). However, from the observations of WADIA (1934, p. 169—170) post-Permian intrusions may be expected as well.

The village Lar is in the centre of the granite complex which has a thickness of at least 1000 m. Granitic and lamprophyric dikes have been observed. In the higher parts (N of Lar) zones of phyllite and psammite schist are enclosed in the granite. Shearing was locally superimposed on the intrusive contacts.

The metagranite is overlain by characteristic Chail-Tanol rocks. The boundary is crossed at the small river 1.5 km N of Lar. We find an alternation (cm to m rhythm) of dark-to light grey, green, silvery phyllites, sericite schists, white and green quartzites, psammite schists, and conglomerate schists. The components of the conglomeratic layers, consist of quartzite, psammite schist, slate mainly of the own formation, and grey dolomite. They show much elongation (1 : 3); the spindle-shaped boulders may attain lengths of 20 cm. The matrix is schistose-phyllitic, or quartzitic. Also arkose-schists have been observed (W of Bharansal). The series resembles the coarse-clastic Chail facies of Nepal (FUCHS, 1967, p. 54—55).

From Bharansal over Gulabgarh and farther upstream the trail follows the axis of an NW-SE striking anticline. Thus going upstream from Gulabgarh we remain in the clastic series, the grade of metamorphism, however, decreases. The phyllites become replaced by dark grey, black, brown, and violet slates. Desiccation cracks have been observed. There are dark grey and white quartzites, grey brown, violet, fine-to medium-grained sandstones, and quartzitic sandstones. Cross-bedding, oscillation ripple marks, and clay gall breccias are frequent. In the conglomeratic layers pebbles and boulders of carbonate rock, quartz, volcanic rock, slate etc. are embedded in a slate or sandstone matrix. The shape of the components is angular or well-rounded. This series is overlain by the Panjal Trap and doubtless it represents the Agglomeratic Slate. It is significant that it is impossible to separate the Chail-Tanol rocks from the overlying Agglomeratic Slate. From here the same has been reported by MIDDLEMISS (1809, p. 288—289), but this is not the only instance of a gradation from Tanol into the Agglomeratic Slate (Gulmarg, WADIA, 1934, p. 153; MIDDLEMISS, 1911; Chamba-Pangi, FUCHS & GUPTA, 1971, p. 85).

On the ascent to the Gulabgarh Pass (Didam Gali) one comes from the Agglomeratic Slate into a thick succession of Panjal Trap, into Gondwanas, Zewan Formation and Lower Triassic limestone. The latter forms the core of a syncline (at the pass). MIDDLEMISS (1909, p. 288—297) gives a detailed description of that section.

Review: In the Riasi-Gulabgarh section we find the following structural units (from S to N):

1. The Siwaliks: Folded M. Miocene to Pleistocene molasse deposits.
2. The Murree Zone: Along steep angle thrusts and in anticlines Shalis (Permo-Carboniferous?) are exposed, overlain by Paleocene — L. Miocene strata. The zone is much folded but autochthonous.
3. The Parautochthonous Zone: It is thrust onto the Murree Zone. The sequence of the unit seems to represent a normal Proterozoic-Permo-Carboniferous succession; probably it also comprises Paleocene-Eocene beds. We have not found recumbent folds as reported by WADIA (1929).
4. The Chail Nappe: The epimetamorphic Chails intruded by granite-gneiss are the southern continuation of the Chail Nappe which is exposed in the Kishtwar Window (see 1.1.5 and 1.2.1). It is an outstanding fact that the garnet-kyanite gneisses, magmatites etc., which form the basal crystalline complex of the Crystalline Nappe [1]) at Kishtwar, are missing from the Pir Panjal Range as from Chamba.
5. The Crystalline Nappe:
   There is no doubt that the succession Chail-Tanol, Agglomeratic Slate, Panjal Trap, Gondwanas, Zewan Formation, Lower Triassic forms part of the Crystalline Nappe. It is a problem whether the Chail Nappe is separable from the Crystalline Nappe and where the structural boundary should be drawn. This is a problem common to Kashmir and Chamba, a full discussion is given in chapter 2.4.
   Here it should be noted that I assume a thrust at Shidaul between the lower granite-gneiss (Chail Nappe) and the Chail-Tanols which are intruded by more massive metagranites (Crystalline Nappe). As observed in all the Himalayas the metamorphism of the Crystalline Nappe dies out in the overlying sedimentary cover.

1.1.2. The Apharwat Area

The region is situated in the Pir Panjal Range at Gulmarg, NW of the section described in the preceding chapter. WADIA in his paper on NW-Kashmir (1934) has reported three occurrences of Tanols in the Pir Panjal Range. From literature the resemblance of Chails and Tanols seemed to be very close and therefore the study of the Tanol Formation and its relations to the surrounding Palaeozoic succession may throw light on the age problem of the Lower Himalayan sequence.

In the political situation of 1969 the Gulmarg-Apharwat occurrence of Tanols was the only one accessible to foreigners. Apparently it is the continuation of the Tanol-Chails of Gulabgarh.

WADIA (1934, p. 148—150) has described an unconformity at the base of the Tanols. Structurally the Tanols of the Apharwat section should be laid in 2 or 3 recumbent folds (see his fig. 2). On the contrary our investigations have shown that the Tanols form a member in the isoclinal Dogra Slate-Panjal Volcanic succession. This sequence forms the SW-limb of the great Kashmir Synclinorium. Though folded and inverted, the sedimentary structures show no structural repetitions in the sequence (compare fig. 2, p. 149, WADIA, 1934, with fig. 6 of the present paper).

The Dogra Slates the lowest exposed formation outcrops N of Zajur Gali already. According to WADIA's map

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[1]) The term Kashmir Nappe was used by WADIA for the whole sequence overlying his Autochthonous Fold Belt.
It is now divided into the Chail- and Crystalline Nappes.

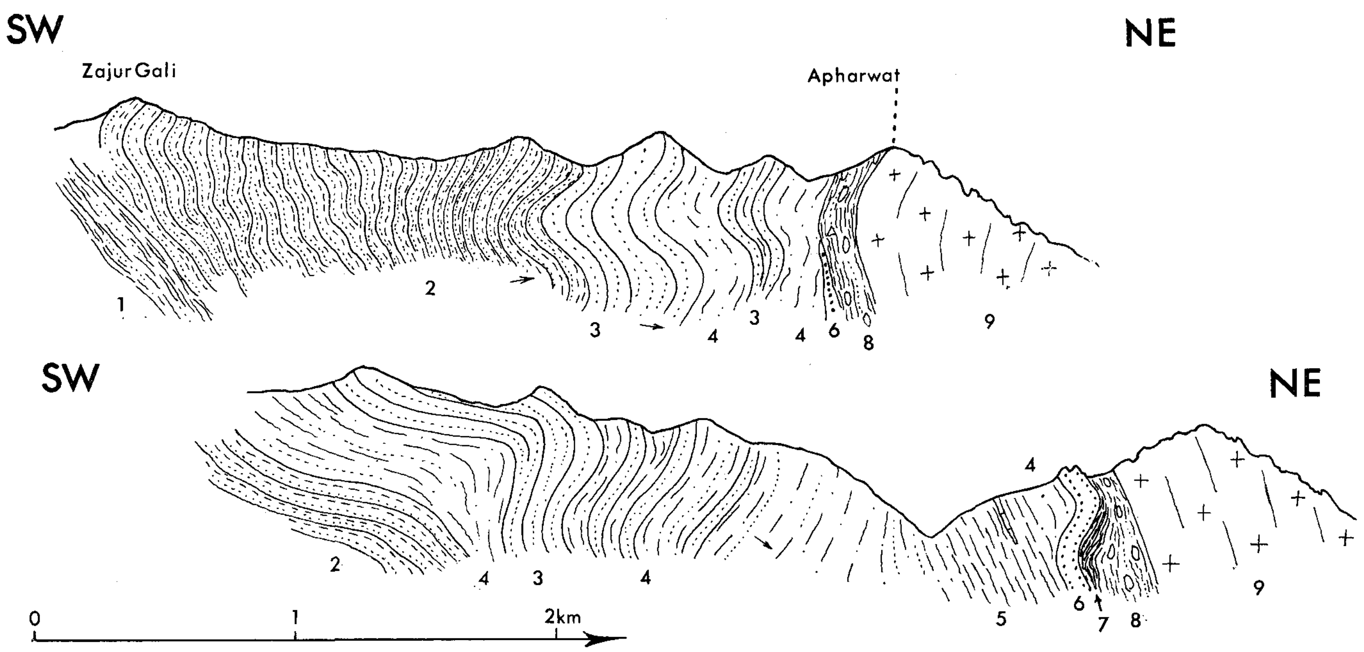


Fig. 6.
Sections through the Apharwat area of the Pir Panjal Range, Kashmir.
1 Dogra Slates
2 Zajur Formation
3 Tanol orthoquartzites (Muth)
4 Tanol phyllites, siltstones, quartzites
5 Tanol dark slates and phyllites
6 Quartzite (Fenestella Shales or Agglomeratic Slate)
7 Dark slates } Agglomeratic Slate
8 Pebbly mudstones } Agglomeratic Slate
9 Panjal Trap
Arrows point towards top

there should be Tanols and the Dogra Slates should begin further SW. In the Zajur area we have studied only the uppermost part of the Dogra Slates.

The lithology is flyschoid: laminated slates and siltstones alternate with layers of impure sandstone. The colours of the rocks are green to grey. Graded bedding, flute casts, rill marks various tool marks, etc. are frequent. The resemblance to Hazara Slates or Simla Slates is very close.

It is significant that we found no break in sedimentation at the top of the Dogra Slates. The arenaceous content increases and the Dogra Slates grade into the overlying beds.

Zajur Formation: Between the Dogra Slates and the Tanols (sensu stricto) we find a formation which may be distinguished from the latter and named from Zajur peak, as its NE-face and the area immediately NE of it are formed by these rocks (74° 19′ 9″ E of Grw., 34° 1′ 20″ N).

In contrast to the underlying slates the rocks weather in massive blocks. They are banded and exhibit bright colours, red brown, violet, light green, light grey, and yellowish. The impression of the sequence seen from a distance is thick-bedded. Fine-grained sandstones, argillaceous sandstones and quartzites, siltstones, sericitic schists, and slates alternate in a m— to mm — rhythm. Graded bedding is conspicuous. Current bedding, erosion channels, ripple cross-laminations, ripple-load convolutions, fine linguoid flute casts and clay gall breccias indicate a turbidite environment (Fig. 7, 8, 10 on Pl. 6; Fig. 9). Small-scale unconformities, lenticular bedding, laminations, which laterally die away etc., are characteristic. Contemporaneously disturbed beds are common with slump folding, and flame structures. Pyrite crystals which are not rare and burrows suggest somewhat reducing conditions.

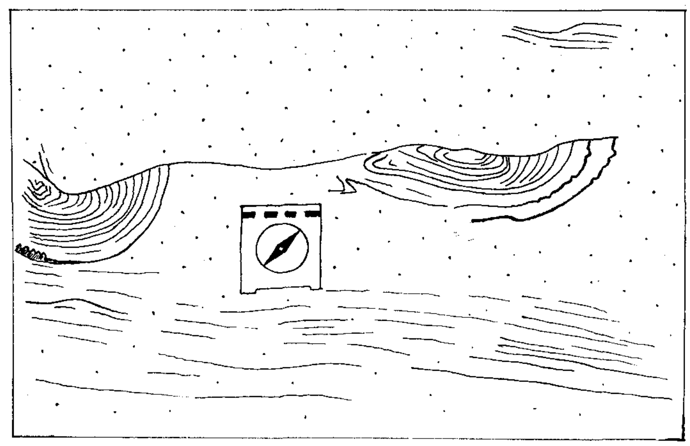


Fig. 9. Ripple-load convolutions and flame structures in siltstone of Zajur Formation, N of Zajur Gali, Pir Panjal. Size given by compass; drawn after a photo.

All these sedimentary features indicate rapid and rhythmic sedimentation in an environment which apparently was controlled by turbidity currents.

The type of sedimentation, and colours etc. show surprising similarity with the arenaceous and silty facies of the Dhaulagiri Limestone from the Kanjiroba area, W-Nepal (Fuchs & Frank,

PLATE 6

Fig. 7. Graded bedding and current bedding in Zajur Formation. Note erosion channel in upper right portion of the picture. N of Zajur Gali, Pir Panjal. Photo: W. Frank.

Fig. 8. Graded bedding and load convolutions in Zajur Formation, N of Zajur, Pir Panjal Range.

Some of the photos had to be turned, the arrows point to the top of the pictures.

Fig. 10. Graded bedding and synsedimentary deformation in siltstone of the Zajur Formation; N of Zajur Gali, Pir Panjal Range. Photo: W. Frank.

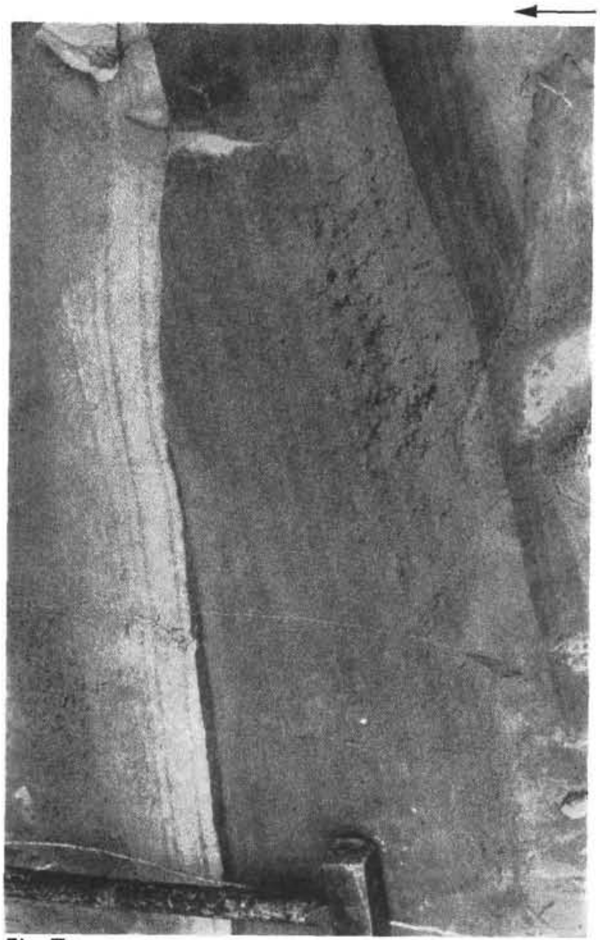


Fig.7

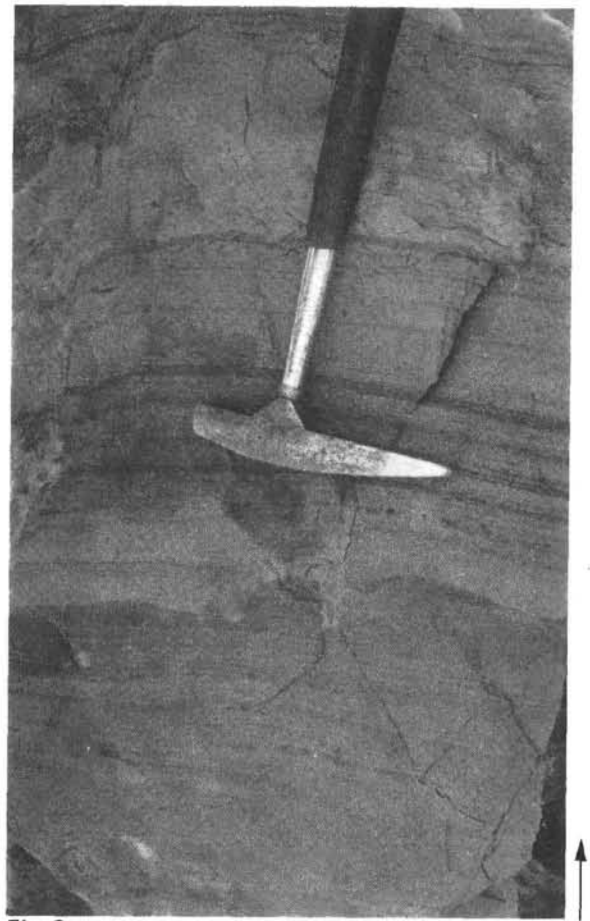


Fig.8

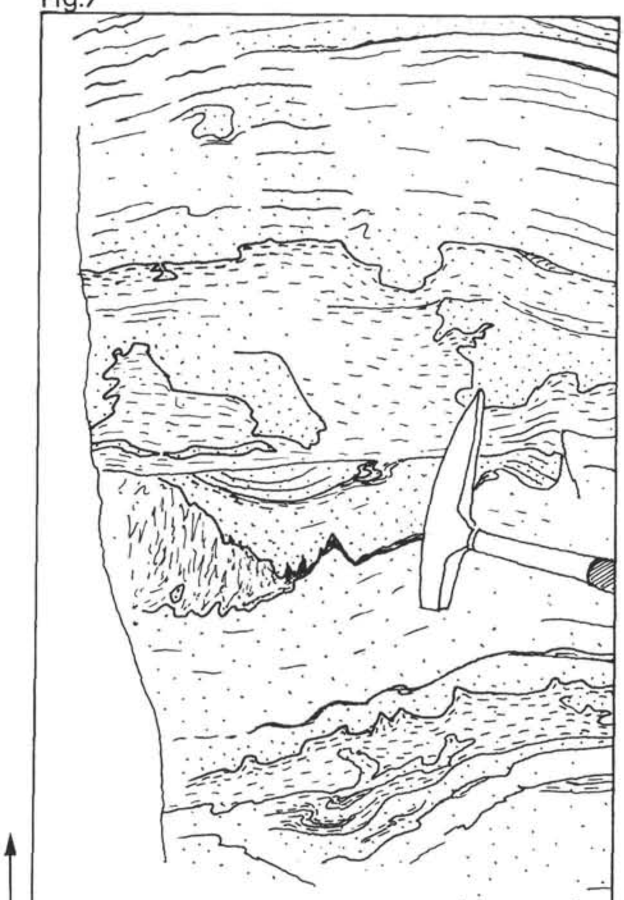


Fig.10a

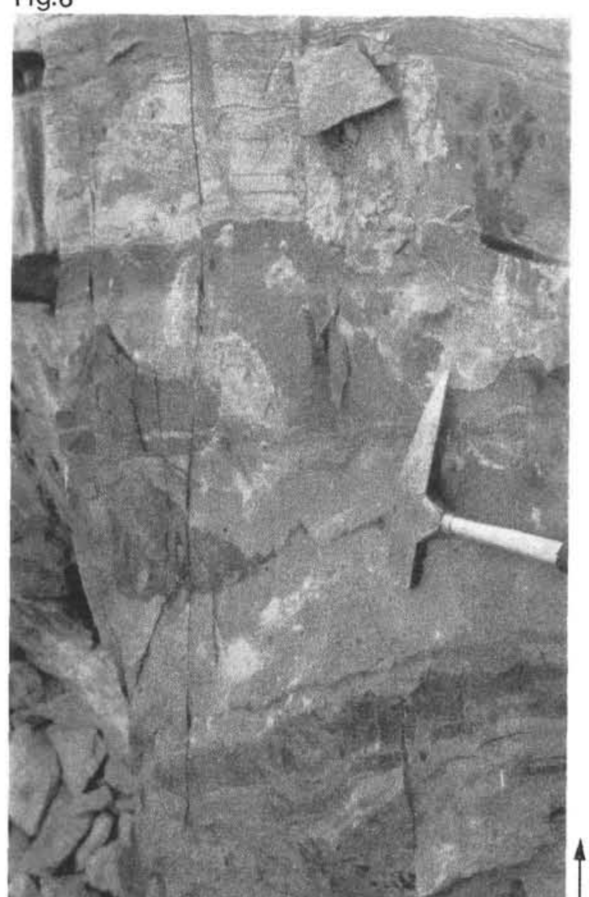


Fig.10b

1970, p. 49—54). The Garbyang Formation of Kumaon (HEIM & GANSSER, 1939, GANSSER, 1964, p. 117), and the Sangsing La Quartzites of Bhutan (GANSSER, 1964, 198—199, fig. 68—71) are rather close. Probably all the named formations correspond roughly also in age. The thickness of the Zajur Formation, however, ranging up to about 800 m, is small compared with the named formations which are several thousand meters thick.

The Tanol Formation: There is no break in sedimentation at the top of the Zajur Formation. The brownish colours change to the green, white, and light grey of the Tanols and the grain size increases. No standard section of the Tanols can be given. Massive quartzites, quartzitic schists, psammite schists, schistose siltstones, and phyllites alternate in varying quantities and replace each other in lateral direction. Fig. 11 (on Pl. 7), for instance, shows a unit of cross-bedded massive quartzite at the base of the Tanols on the Apharwat-Zajur ridge, whereas there is an argillaceous unit between this quartzite and the Zajur Formation in the valley E of the ridge. In the eastern section there is a slate-phyllite member in the upper part, which is missing S of Apharwat. Such rapid lateral variations are characteristic for the Tanols and further examples will be given in this paper. Besides the rock types this is another feature in common with the Chails (FUCHS, 1967; FUCHS & FRANK, 1970, 33—37).

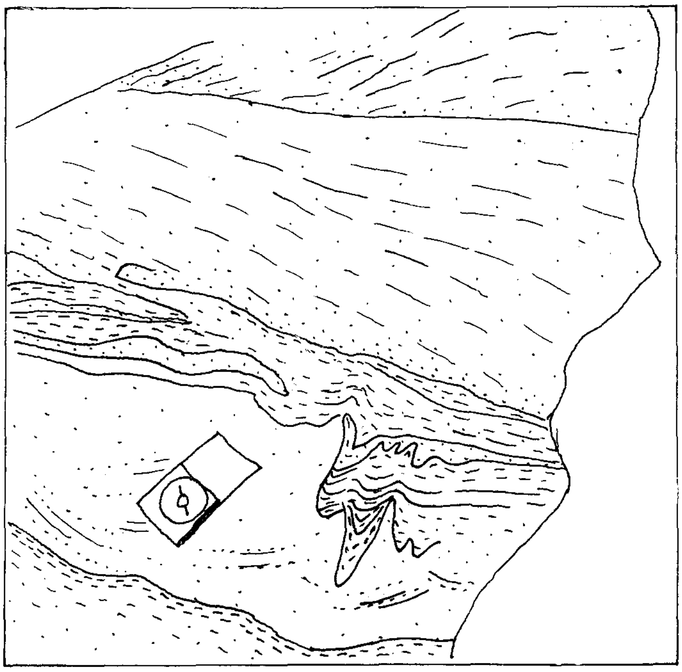


Fig. 12. Graded bedding, current bedding, ripple-load convolutions indicate rhythmic and rather turbulent sedimentation. Tanols from the valley E of Apharwat, Pir Panjal. Drawn after photo.

In the Apharwat region the more argillaceous rocks predominate: schistose siltstones, psammite schists with layers of phyllite or sericite quartzite. The rocks are finely laminated or layered. Varying content of arenaceous matter reflects rhythmic sedimentation (mm to 0.5 m). Most of the laminae and layers are graded. The arenaceous parts frequently exhibit current ripple cross-laminations, ripple-load convolutions, load convolutions etc. (Fig. 12, 13 [on Pl. 7]). Intraformational folding, crumpling, squeezing of certain beds and other synsedimentary deformations are common (Fig. 14 on Pl. 7).

There are zones rich in quartzite (see Fig. 6) which may attain several hundred meters thickness. The quartzites are thick-bedded and alternate with the rocks described above. Common cross-bedding and not so frequent oscillation ripple marks suggest deposition in an agitated and not too deep environment (Fig. 15 on Pl. 7). But there are also sole marks, such as flute casts (Fig. 16 on Pl. 8), rill marks, which are in good agreement with the flyschoid character of the formation.

As mentioned above there is a zone of dark grey slates and phyllitic rocks (300—400 m) in the upper part of the Tanols (lower section of Fig. 6).

The whole sequence shows metamorphic alterations (greenschist facies) but these are conspicuous particularly in the mixed arenaceous-argillaceous rocks.

The original thickness of the Tanols in the described area may lie around 1000 m.

The Tanol quartzites resemble the Muth Quartzite or the quartzite facies of the Chails. The arenaceous — argillaceous sequence shows rocks typical for Chandpurs and Chails. The flysch character, however, generally is absent in most occurrences of these formations, it only has been observed as a local development of the Chails in the Thulo Bheri valley (W Nepal, FUCHS & FRANK, 1970, p. 34). This facies shows striking similarity with the Apharwat Tanols.

The Agglomeratic Slate: Between the schistose Tanols and the typical dark and pebbly slates of the Agglomeratic Slate there is a marked quartzite horizon (40—50 m) in the area E of Apharwat (Fig. 6). This quartzite thins out towards the W. My co-worker Dr. FRANK has found a slight angular unconformity at the base of the quartzite which makes it probable that it does not belong to the underlying Tanols, but is part of the Upper Palaeozoic. It may represent the Fenestella Shales which in certain areas, e. g. Marbal Pass, are replaced by quartzite. Lithologically similar quartzites are common in the Fenestella Shales, but also in the Agglomeratic Slate. In absence of fossils it is not to decide to which of the two formations the quartzite belongs.

The basal bed of the quartzite is somewhat conglomeratic, pebble sizes reach 1 cm diameter. The main part is thick-bedded breaking in big blocks. It is of light colour and frequently cross-bedded. The grain size varies from fine to coarse. Layers of intraformational breccia have been observed. There is a 0.5 m layer of carbonate quartzite 1 m below the top. In its topmost layer the quartzite becomes dark coloured and locally fine-conglomeratic. Black and dark grey, partly laminated slates overlie. The contact is a little disturbed in the section described.

About 30—40 m above the base the dark slates become conglomeratic, layers of conglomeratic sandstone and rare ferruginously weathering dolomites appear. The sequence from the top of the quartzite to the base of the overlying Panjal Trap has a thickness of ca. 200 m.

Apart from the typical lithology of the Agglomeratic Slate it may be cited that MIDDLEMISS (1911) and WADIA (1934, p. 152) have found a horizon containing Gondwana plants near Apharwat, which leaves no doubt on the age of the formation.

PLATE 7

Fig. 11. Current bedding in orthoquartzite (Muth) of the Tanol Formation S of Apharwat, Pir Panjal Range.

Fig. 13. Cross-bedding, graded bedding, and ripple-load convolutions in the Tanols ESE of Apharwat, Pir Panjal Range. Top is on the right hand side of the picture.

Fig. 14. Ripple-load convolutions and other synsedimentary deformations in laminated psammite schists of the Tanols. SE of Apharwat. Photo: W. FRANK.

Fig. 15. Oscillation ripple marks, partly branching, in the Tanols, SE of Apharwat, Pir Panjal Range. Photo: W. FRANK.

PLATE 7


Fig.11


Fig.13


Fig. 14

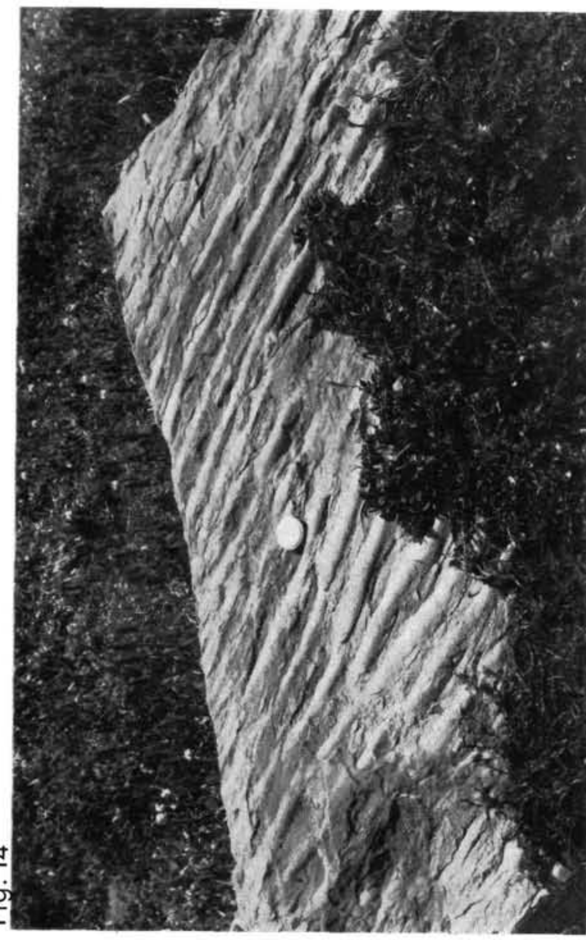


Fig.15

PLATE 8

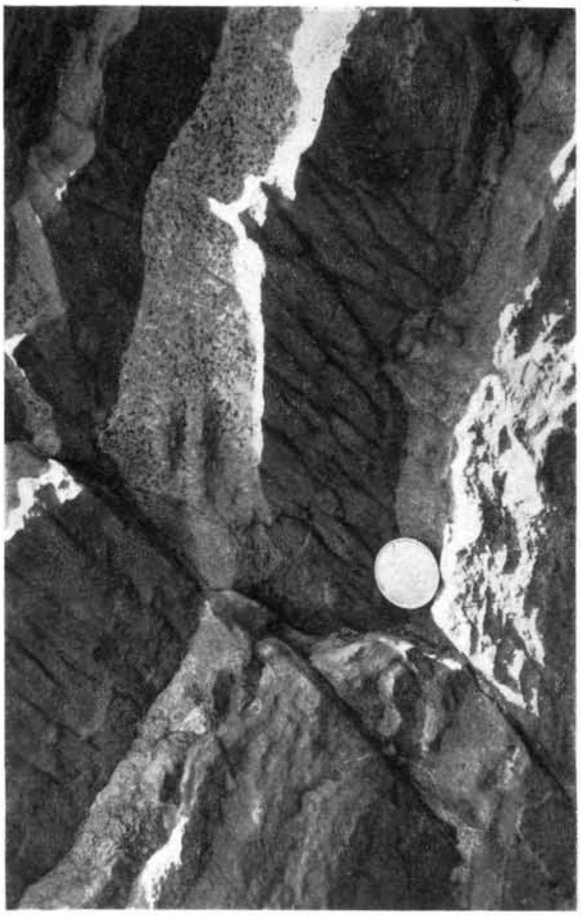


Fig.16

Fig.22

Fig.24

Fig.25

PLATE 8

Fig. 16. Tanol quartzites showing flute casts on sole planes; SE of Apharwat, Pir Panjal Range.

Fig. 22. Two-mica granite-gneiss with pegmatoid veinlets. Chenab bridge NW of Kishtwar.

Fig. 24. Chail phyllites (1) with veinlets and lenticles of quartz are discordantly cut by metagranite (2). The latter shows a fine-grained marginal zone (3). Chandra valley.

Fig. 25. Medium-grained, rather massive metagranite with sporadic „schlieren" and patches rich in biotite; intrusion in the Chails of the Kishtwar Window, Chandra valley.

Review: The Dogra Slate-Panjal Trap succession spans a time interval from Late Precambrian or Early Palaeozoic to Up. Carboniferous or Permian. Sedimentation, typical for the deposition in an unstable trough, was continuous from the Dogra Slates to the top of the Tanols. However, there are two marked changes in facies, at the base of the Zajur Formation and of the Tanols respectively.

These facial changes, in my view, reflect successive stages of disturbance in the course of the Caledonian orogeny. The Late Precambrian-Early Palaeozoic geosynclinal sedimentation (Dogra Slates) was replaced by orogenic deposits (Zajur- and Tanol) Formations. The grain size of the detritus became increased under the influence of movements in nearby zones; but sedimentation was not interrupted in the area studied. The quartzite zones in the Tanols apparently are intertonguings of the flyschoid Tanol- and the Muth Quartzite facies.

The only unconformity mentioned above seems to indicate Variscan disturbances which were followed by the deposition of the quartzite (Fenestella Shales?) and the Agglomeratic Slate.

Anyhow, the section shows very clearly that the Tanols do not facially replace the Dogra Slates but are younger and bridge the gap between Early Palaeozoic and Up. Carboniferous as already emphasized by WADIA (1934).

1.1.3. The Kolahoi-Basmai Anticline (Liddar valley)

The area is situated ENE from Srinagar in the middle course of the Sind river and in the upper part of the Western Liddar valley. We are here in the Great Himalaya Range, the Zanskar Range, which is NE of the Kashmir Basin, whereas the areas described in the preceding pages are in the Pir Panjal Range SW of the valley of Kashmir.

The region has been described by BION & MIDDLEMISS (1928) and reference is given in PASCOE (1959). In the limbs of the Basmai Anticline we find the sequence Cambro-Ordovician, Silurian, Muth Quartzite (Devonian), Syringothyris Limestone (Lower Carboniferous), Fenestella Shales?, Agglomeratic Slate, Panjal Trap (U. Carboniferous-Permian). Locally certain members of this succession may be missing.

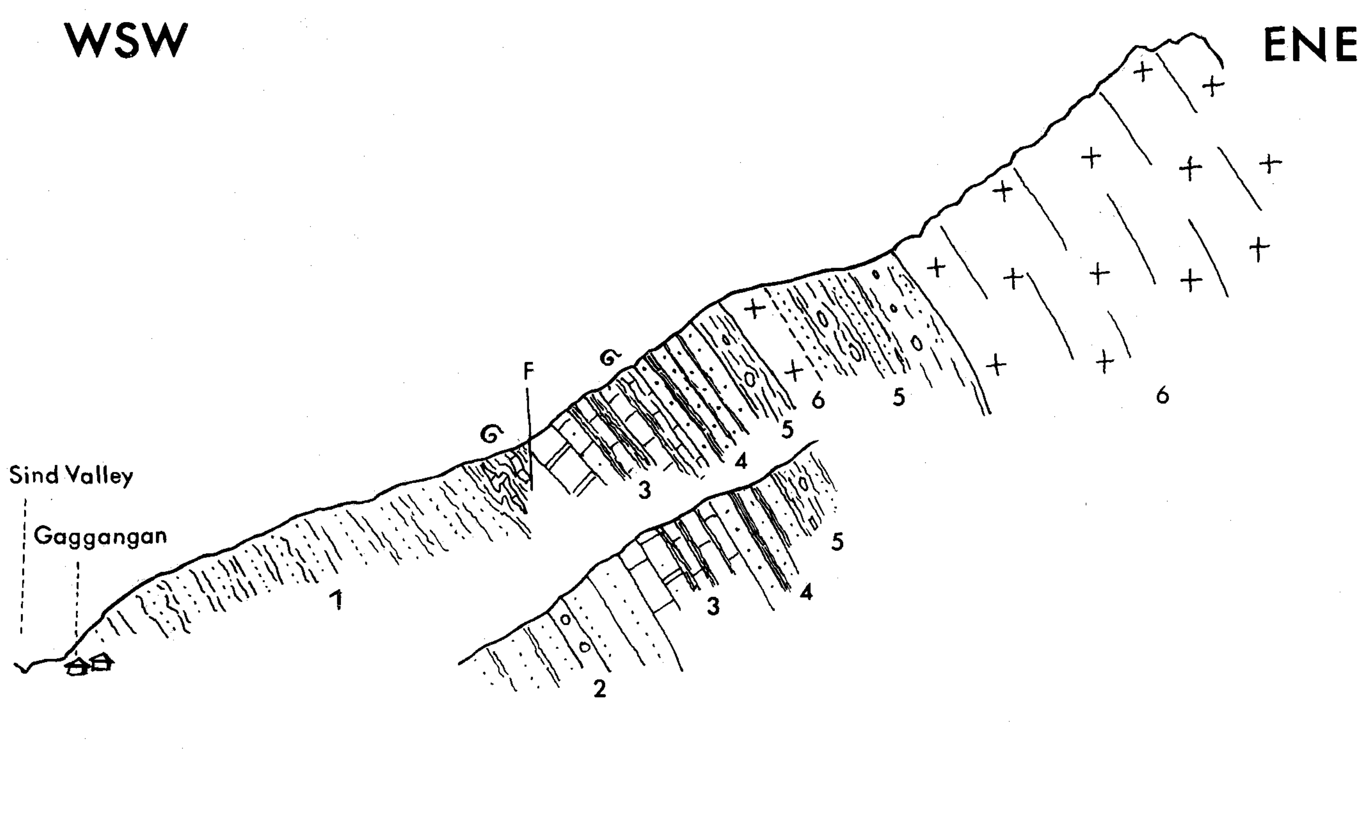
As it was one of our main objects in Kashmir to prove the relation and possible correspondence of Muth-Tanol-Chail, we visited the Basmai area. First I shall describe a section ENE of the village Gaggangan (Gagangair) in the Sind valley and then a traverse E of Basmai Peak (W-Liddar valley).

1.1.3.1. The Gaggangan (Gagangair) Section:

Going upstream the Sind valley to the village Gaggangan one has to traverse a thick and rather monotonous succession referred to Lower Cambrian by PASCOE (1959, map, p. 639). The rocks are green to grey, dark grey slates, phyllites, silty or arenaceous slates, siltstones and impure quartzites and greywackes. The rocks show irregular s-planes, burrows and hieroglyphs are frequent. Lamination and graded bedding are locally developed. Characteristic are unstratified quartzitic sandstones and greywackes full of irregular layers and lenses of phyllite. Activity of boring animals and synsedimentary disturbance by slumping etc. seem to be responsible for these peculiar rocks.

From Gaggangan we followed a nala (small ravine) towards NE (Fig. 17). The lower part of the section consists of the

Fig. 17. Sections at Gaggangan, Sind valley, Kashmir;
1 Cambro-Ordovician
2 Muth Quartzite
3 Syringothyris Limestones
4 Fenestella Shales (?)
5 Agglomeratic Slate
6 Panjal Trap
Length of the section ca. 3 km



rock assemblage described above. Then come dark slates containing lenticular bodies of crinoid limestone up to 4 m thick. The limestone is dark coloured and shows ferruginous weathering. It yielded indeterminable remains of trilobites or brachiopoda. The crinoids indicate that this horizon is already higher than Cambrian. From comparison with other sections (Liddar valley, Basmai) I suggest an Ordovician or Silurian age.

Along a disturbed zone the dark slates abut the Syringothyris Limestone. The intervening Muth Quartzite seems to be cut out by a fault.

The Syringothyris Limestone, ca. 150 m thick, consists of dark dolomites and limestones, light grey limestones, and calcareous sandstones, arenaceous dolomites, green and grey carbonate quartzites, and dark grey to black slates. Limestone and slate may alternate forming laminated or layered rocks, the formation, however, is mainly thick-bedded. The arenaceous carbonate rocks frequently exhibit cross-bedding. Rare intraformational breccias have been observed. Light calc schists formig the top of the formation yielded numerous crinoids.

With a sharp boundary 70 m of a slate-quartzite series follow: green, white, or dark grey, frequently coarse-grained quartzites and sandstones alternate with dark slates. There are also fine-conglomeratic layers in the quartzite. In white quartzite sometimes there are dark coloured streaks and patches. The succession is rather thick-bedded.

Fossils are absent and from lithology it is not to decide whether the beds overlying the Syringothyris Limestone are Fenestella Shales or Agglomeratic Slate.

Certainly the succeeding 40 m of dark and green micaceous slates belong to the Agglomeratic Slate. They contain the characteristic sporadically embedded pebbles.

Then comes Panjal Trap, but, as shown by blocks fallen from higher parts of the slope, the trap is overlain again by Agglomeratic Slate. We find light and dark quartzite, conglomerates, and black slates.

The Muth Quartzite, which is missing in the section described, may be studied ENE from the village Gaggangan: The thick-bedded medium to coarse-grained quartzite breaks in big blocks. It is rather pure, white or green and shows cross-stratification. Conglomeratic layers in the quartzite are not infrequent. The components of the conglomerates are quartzite and phyllite.

Subordinate there are green and silvery psammite schists with occasional schistose conglomerates and sericite phyllites partly laminated.

The lithological similarity of these rocks with the Chails of the Lower Himalayas is striking.

1.1.3.2. The Section E of Basmai

In the uppermost Western Liddar valley the Basmai Anticline plunges ESE towards Kolahoi Peak (1799'). The Kolahoi is built up by Panjal Trap; at the camp ground at its northwestern foot the upper part of the Agglomeratic Slate is exposed. The rocks are: dark slates, tuffs, shaley sandstones, grey calcareous sandstones to arenaceous limestones, and white to dark grey, massive quartzites. Conglomeratic and breccia layers are frequent. Intercalations of trap are common.

A shaley horizon in this series has yielded crinoids and brachiopoda. The palaeontological examination by Dr. V. J. Gupta (Geological Dept. of Panjab University, Chandigarh) has shown an Uralian age:

Spirifer nagmargensis Bion
Spirifer nitiensis Diener (?)
Spirifer keilhavii Buch
Spirifer cf. *kimsari* (Bion)

These fossils indicate correlation with the upper fossil horizon of the Agglomeratic Slate (Middlemiss & Bion, 1928).

Farther NW a fine section through the Palaeozoic sequence of the Basmai Anticline is exposed along a northwestern tributary of the Liddar river (Pl. 3).

Ascending from the Liddar valley we find steeply S dipping black arenaceous or silty shales and slates along the gorge of the stream which comes from the W. In the rocks flaser bedding and current bedding are common. These beds belong to the upper part of the Agglomeratic Slate which is overlain by the Panjal Trap in the SW.

At the branching we follow up the valley towards NNE. There we cross the SW limb of the anticline and successively come in older beds.

First we find a rhythmic alternation (1—5 m) of dark silty shales and slates, sandstones, quartzites, and conglomerates (1). The sequence of these rocks reflects cyclicity. Most units start with a bed of conglomerate-quartzite. The components quartz, quartzite, feldspar, slate, granite etc. range up to sizes of 12 cm and show angular to well-rounded shapes. Gradation into fine-conglomeratic quartzite and quartzite is frequent. These rocks are dark grey, green, or white and may exhibit cross-bedding. Shaley sandstones or silty dark shales and slates form the top of a rhythmic unit. Occasional pebbles and cobbles, which are sporadically embedded in certain beds, give a tilloid character.

It follows a 80 m zone particularly rich in conglomerates (2). The matrix may be shale, sandstone, or quartzite. Besides the components listed above we also find light dolomite and limestone showing ferruginous weathering. The components reach sizes of 30 cm. The beds are partly rather ill-sorted.

After ca. 15 m of dark quartzite and slate (3), we cross white to grey massive, fine-grained quartzite, 10 m thick, exhibiting cross-bedding (4).

Black slates (ca. 30 m) follow (5). At their stratigraphic base a 1.5 m bed of blue marly limestone is full of crinoids and also contains ill-preserved brachiopoda and corals (F 2). Sporadic boulders (sandstone and quartz) up to 30 cm diameter are embedded in this limestone. The rock is terminated by a fault.

Dark slates with a 1.5 m layer of light greenish tuffaceous rock, and an fenestellid horizon (F 3, 2 m) follow. After 1.5 m of crinoid limestone we get into an alternation of black to dark grey slates, siltstones, green sandstones, white and dark grey quartzites, with limestone and marl layers (ca. 60 m) (6). These beds yielded crinoids and ill-preserved brachiopods.

White to light grey, massive, and thick-bedded quartzite, ca. 25 m, follows (7). There are only few and very thin intercalations of dark shale from which the clay gall breccias in the quartzite are derived. Current bedding is not rare in the quartzite.

After a sill of diabase we come into 25 m of dark grey arenaceous slates, shaley sandstones and thin-bedded or schistose quartzites (8). A cast of *Euryspirifer speciosus* Bronn (?) has been found in these beds (F 4). According to Dr. V. J. Gupta (Panjab University, Chandigarh), who has examined the fossil, it indicates a Middle Devonian age.

There is a gradation over dark grey quartzite into light thick-bedded quartzite (ca. 20 m) (9). Again we find a sill of diabase (ca. 18 m). Then follow 7 m of quartzite, and 8 m of dark slate with bluish, ferruginous carbonate quartzite containing crinoid ossicles. Light quarzite (2 m) is followed by a 20 m of dark silty slates (11). Then comes light greenish quartzite (4 m), which grades into arenaceous limestone (ca. 4 m). This ferruginously weathering rock exhibits cross-bedding and contains crinoid debris (12). Next come diabase (5 m), carbonate quartzite (2 m), dark grey arenaceous slates (ca. 15 m), carbonate quartzite (1 m) containing crinoids, light siltstone (1.5 m), schistose carbonate quartzite to arenaceous limestone partly breccious (6 m), cross-bedded carbonate quartzite (4 m), carbonate slate with crinoids grading into black splintery slates with dark quartzitic layers (12 m) (13).

After this variety of beds we come into first grey then light quartzite (ca. 40 m) (14). From the talus it may be assumed that there are also conglomerate-quartzites and psammite schists as well as quartzite with ripple marks.

Then come 7—10 m of light grey somewhat siliceous dolomite weathering yellow to khaki (15). The well-bedded rocks also contain arenaceous current-bedded layers. The s-planes are sericitic-phyllitic. At their base they become thin-bedded and grade into 10 m of platey to schistose sericite quartzite and arenaceous sericite schist. Ripple marks indicate shallow-water deposition. The above beds grade into a ca. 200 m complex of quartzite and conglomerate-quartzite (16). The thin to thick-bedded rocks are light green to white and frequently show cross-bedding, top being in SW. The conglomeratic layers may attain 10 m thickness. The components, commonly well-rounded may range up to 30 cm diameter.

At the base we find a gradation (5 m) from thin-bedded, light sericite quartzite with phyllite layers to grey silty slates and schistose sandstones. In the latter current bedding and flaser structures are common.

There are about 40 m of dirty grey coloured, silty to arenaceous, micaceous slates (17). Then we find a lenticular body (up to 20 m) of grey hard partly nodular limestone. With tectonic contact it abuts against a series of laminated sericite phyllites, psammite schists with bands or lenticular bodies of limestone or ferruginous dolomite (up to 15 m thickness). The limestones are commonly fine-crystalline, light coloured and rich in crinoids. The latter contrast from the matrix by their dark grey colour. There are also small bodies of diabase in this series. The total thickness of the series (18), which forms the core of the anticline, is 300—350 m. Thick-bedded to massive greenish and white quartzites and conglomerate-quartzites lie above a poorly exposed contact. Current bedding indicates top in the NE being in the northern limb of the anticline.

The quartzite is succeeded by a 30 m alternation of well-bedded, light grey siliceous dolomite, limestone laminated with sericite phyllite, and psammite schists (20). The carbonate rocks are prevalent (ca. 80%). Large crystals of pyrite (2 cm) are frequent.

50 meters of pure quartzite, conglomerate-quarzite, psammite schist, and sericite schist follow above the carbonate horizon (21).

It overlies a carbonate formation (Syringothyris Limestone, 150—180 m) with ca. 25 m dark grey, partly marly limestone (22), ca. 20 m of light grey, arenaceous dolomite with undeterminable fossil remains (23); then dark grey marls and limestones (24) rich in brachiopods, corals, and crinoids (20 m). Locally these rocks contain chert. They are succeeded by 12 m of light, current bedded carbonate quartzite to arenaceous dolomite with layers of pure, white quartzite (25) followed by dark grey limestones, partly schistose and light grey dolomites (20 m) (26). Arenaceous layers exhibit graded bedding. The beds contain crinoids and brachiopoda. The uppermost exposed bed of the Syringothyris Limestone consists of marly limestone (4 m) containing angular rock fragments (dm sizes) from the same formation. The boundary against the overlying Agglomeratic Slate seems to run through the basin filled by the lake.

For lack of time I was not able to continue the section towards NE. From the talus and binocular observation a similar content of the Agglomeratic Slate as in the south-western limb of the anticline may be assumed. In the higher part there are intercalations of Panjal Trap, which builds up the range in the N. The formations observed in the northern limb continue towards NW (see upper section in Pl. 3).

Discussion:

The oldest formations of the section described are exposed in the core of the anticline. The dark slates (17) show much lithological resemblance with the Dogra Slates and older Palaeozoic formations. The psammite schists (18) show the characteristic lithology of the Tanols except the frequency of crinoid limestone. However, similar carbonate rocks are found in the Tanols at Tarbela (Hazara), or in the beds below the Muth Quartzite SE of Eishmakam (Kashmir). The crinoids definitely prove a Palaeozoic age.

Due to the strike fault in the centre of the anticline it is not possible to decide whether the beds (18) replace the lower part of the Muth Quartzite and thus are younger than the beds (17) or whether the zone of silty slates is younger. As these slates have not been observed between beds (18) and the Muth Quartzite (19) they could have been pinched out or hidden under fallen blocks of the overlying quartzite. Since, we assume no great hiatus in age between the beds 17 and 18, they most probably represent Ordovician-Silurian.

The Muth Quartzite with its conglomerates, ripple marks, and cross-bedding is a typical shallow-water formation. It contains zones of argillaceous and carbonate rocks. Comparison of the two limbs shows that there are rapid facies changes which do not allow a stratigraphic subdivision of the formation. The southern limb contains several carbonate and argillaceous horizons compared with only one carbonate zone in the N. The fossils found in the formation are confined to the southern limb. In the latter we find the basic volcanic rocks which are missing in the N. The diabases strengthen the lithological similarity of the Muth Quartzite with the Tanols and Chails, however, they could also be related with the younger Panjal volcanism.

Whereas the upper formational boundary of the Muth Quartzite is clearly to be drawn in the N between beds 21 and 22 this is not so in the S. From lithology it seems probable that the quartzites (7) still belong to the Muth Formation, but no typical Syringothyris Limestone is found on top of it as in the N.

It is questionable whether the mixed argillaceous-arenaceous-calcareous beds (6) replace the typical Syringothyris Limestone. Judged from the ill-preserved brachiopods, crinoids, and fenestellidae it can not be ruled out that the beds (6) represent the Fenestella Shales. From observations in other areas (Marbal Pass) we came to the tentative view that Fenestella Shales and Syringothyris Limestone may replace each other partly or possibly also entirely. The bed F 2 shows a striking similarity with the topmost bed of the Syringothyris Limestone at the southern banks of the lake, which hints to a stratigraphic correspondence of bed 6 with the Syringothyris Limestone.

This uncertainty similarly concerns the Fenestella Shales. In the N they may be hidden below the lake, whereas in the S we suppose them being represented by beds 3—5. In absence of fossils nothing definite may be said, as they lithologically could belong to the Agglomeratic Slate as well.

No doubt exists concerning the overlying beds 1—2 which from their lithology are part of the Agglomeratic Slate. Though tuffs are certainly present in the formation, we hold the view that the conglomerates and characteristic pebbly mudstones are not the product of volcanism (Middlemiss, 1910, p. 233—234). Climatic factors — the glaciation of the southern continents — and orogenic disturbances (Hercynian movements) seem more likely causes. On the other hand, the Permo-Carboniferous volcanism of Kashmir certainly was related with the Hercynian movements.

Thus the distinct character of the formation seems to be the product of various factors, a view given in Fuchs & Gupta, (1971, p. 90).

The Basmai section gives a good example of the Palaeozoic sequence, but also shows variability of facies within a small area. The facies changes will be more obvious when we compare the sedimentary developments of Kashmir, Chamba, and Hazara.

1.1.4. Observations from the Palaeozoic sequence of the Liddar valley

Southeastern Kashmir is very important for the stratigraphy of the Palaeozoics. Since the fine description given by MIDDLEMISS (1910) the Liddar valley is a classical area referred in many handbooks, e. g. PASCOE (1959). In the last years V. J. GUPTA has done much stratigraphic work in the neighbouring areas. His studies and fairly complete lists of fossils are summarized in FUCHS & GUPTA (1971). In the present paper only a few additional observations shall be given.

1.1.4.1. The Lokatpura Section

An anticline plunges NW in the lower part of the Liddar valley at Kotsu. Its core is built by Cambrian to Silurian formations. E of Kotsu at Lokatpura we studied a section through the beds underlying the Muth Quartzite (Fig. 18).

The oldest beds forming the ridge behind the village Lokatpura are:

1. Green-grey, drab, silty or arenaceous micaceous slates which locally are laminated and graded. They alternate with grey green greywackes, sandstones, and white to grey quartzites. Burrows are the only found evidences of life activity in this monotonous series.
2. A 30—40 m zone rich in fine-crystalline, light limestone follows. The limestone forms dm - to m - layers interbedded with slate. Ill-preserved remains of crinoids are numerous.
   A lithologically similar horizon is found below Upper Ordovician beds farther E (FUCHS & GUPTA, 1971, p. 79). The numerous crinoids indicate an age not older than Ordovician so that a Lower to Middle Ordovician age is probable for the beds described.
   It is interesting to note that these beds show phyllitic metamorphism whereas the underlying monotonous series seems unmetamorphosed. This observation has many parallels: Dogra Slates, Cambro-Ordovician less altered than Tanols and Muth Quartzite; Simla Slates less altered than Chandpurs and Chails etc. The explanation seems to be that response to slight metamorphism depends largely on the material. Greywacke slate formations apparently are rather resistant and thus do not show visible effects of alteration, which are clearly to be seen in neighbouring beds.
3. Slates and thick-bedded argillaceous sandstones follow.
4. Above we find dark to medium grey, also greenish phyllitic slates of characteristic breccious structure. The partly arenaceous rocks contain numerous flat pebbles of silty slate, diameters varying between 1 and 10 mm. After some tens of meters we find layers containing subangular pebbles (ca. 15 mm) of reddish and grey quartzite and sandstone, followed by greenish grey slates which become less and less brecciaceous. The total thickness of the brecciaceous slates is about 130 m.
5. The character of the overlying beds in the saddle is quite different: The arenaceous sedimentation of the Muth Quartzite starts. In the basal 10—15 m of this quartzite the thick beds of hard, white quartzite are interbedded with dark grey, bleaching arenaceous shales, and carbonate quartzite. These beds are rich in brachiopods, trilobites, crinoids, and plant remains. Dr. V. J. GUPTA kindly has determined the following:

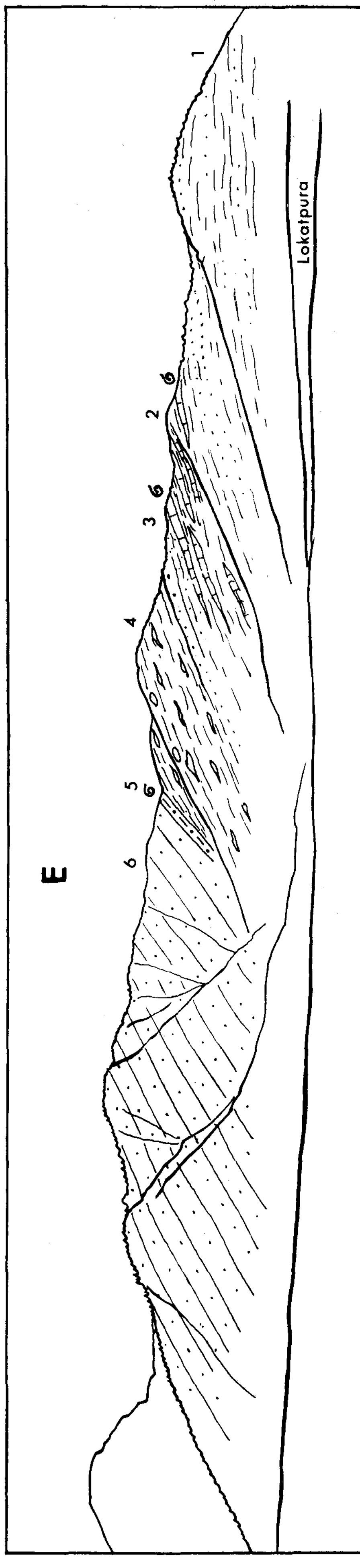


Fig. 18. View of the Lokatpura section SSE of Eishmakam, Liddar valley, seen from the W. Description in the text.

Leptaena rhomboidalis (Wilckens)
Orthis (Dalmanella) basalis Dalman
O. elegantula Dalman
O. (Plectorthis) spitiensis Reed
Calymene blumenbachi (Brogniart) Salter
Pseudoporochnus sp.

These fossils according to Gupta indicate an Upper Silurian age, except the plant fossil which hints to Lower Devonian. Relations with the fauna of the Naubug Beds are obvious. The lithology, however, is a different one. This may indicate that the Muth Quartzite deposition locally started in the Upper Silurian, whereas Gupta holds the view that the Muth Quartzite is entirely Devonian (1969, Fuchs & Gupta, 1971).

6. The fossil horizon is succeeded by light, very hard, thick-bedded quartzite. Few conglomeratic beds have been found. Cross-bedding is frequent. In the mountain of our section ca. 500 m of Muth Quartzite are exposed. We have followed the section only through the lower part of the quartzite.
R e v i e w : The section shows that till Upper Silurian, there were geosynclinal conditions of deposition. The breccia slates (4) may indicate orogenic disturbance which is followed by a marked and rapid change in depositional conditions. Pure, well-sorted arenaceous beds of large thickness follow the monotonous, ill-sorted geosynclinal deposits. This change certainly was brought about by late-Caledonian movements.

1.1.4.2. Kotsu Hill

At the NE side of K o t s u H i l l the upper part of the M u t h Q u a r t z i t e is exposed. The quartzite is thick-bedded and somewhat argillaceous. The colours are white, green, grey, khaki, and rarely slightly purple. Laminations, clay gall breccias, and ripple marks have been observed. Near the bank of the river a layer full of imprints of plants (psilophytes?) was found.

The S y r i n g o t h y r i s L i m e s t o n e seems to develop from the topmost beds of the Muth Quartzite. It consists of dark slates blue, grey dolomites, and quartzitic beds. Brachiopoda and crinoids predominate, and there are also corals gastropods, fenestellidae, and orthoceratids.

The F e n e s t e l l a S h a l e s consist of an alternation of grey to black slates, shaley sandstones and quartzites, greenish quartzitic sandstones, white to grey massive and cross-bedded quartzites, carbonate quartzites, and light to medium grey or bluish limestone. Lithologically the formation is richer in clastic rocks, but the rock types are the same as in the underlying Syringothyris Limestone. Brachiopods, bryozoa, bivalves, etc. abound in certain horizons and plant impressions also have been observed.

1.1.4.3. The Agglomeratic Slate of the Liddar valley.

There are good exposures of the A g g l o m e r a t i c S l a t e along the road leading to Pahlgam (Pailgam) at the W side of the Liddar river. Again we find the alternation of black, green, grey, slates, green to black tuffs, silty to arenaceous micaceous slates, calcareous shales, sandstones, arkose-sandstones, light and grey quartzites and conglomerates. The latter contain rounded to subangular pebbles and boulders (up to 30 cm diameter) of quartzite, phyllite, mica schist, granite,

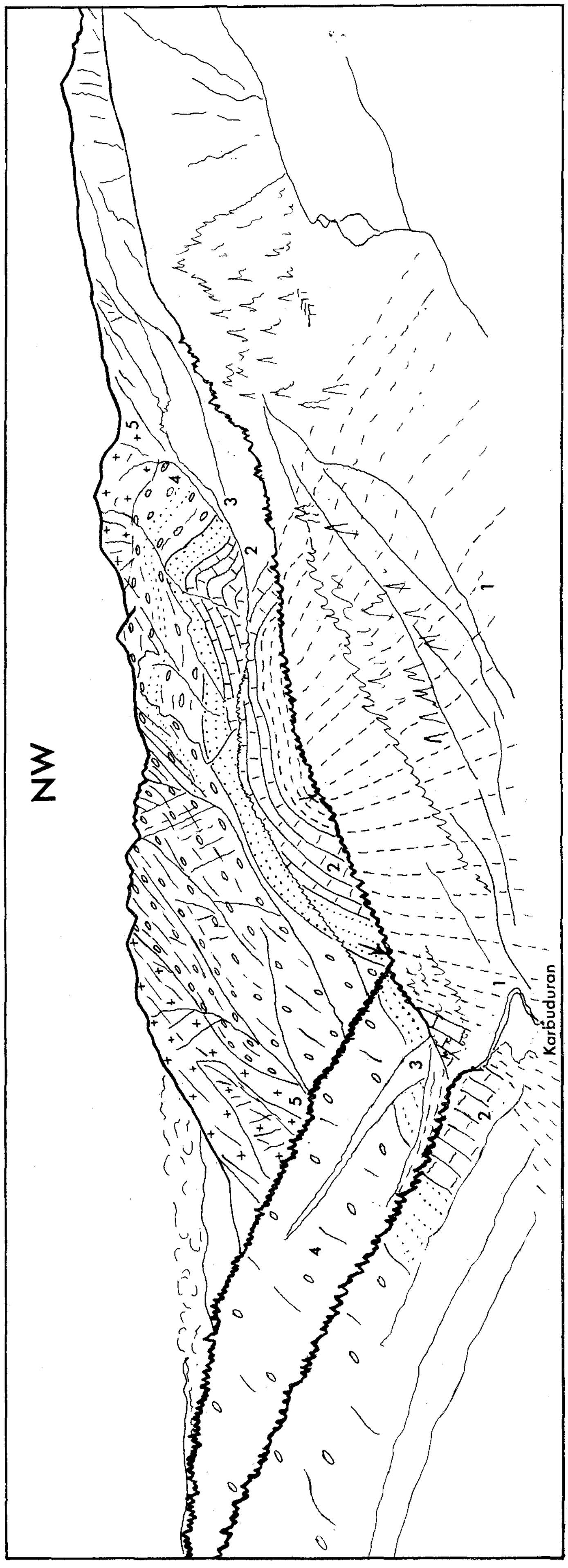


Fig. 19. The Marbal Valley Anticline seen from the Marbal Pass down the Marbal valley.

1 Tanols
2 Syringothyris Limestone
3 Fenestella Shales (here rich in quartzite)
4 Agglomeratic Slate
5 Panjal Trap

Arrows indicate the section Fig. 20.

quartz porphyry, slate, sandstone, and dolomite in a matrix of slate, sandstone, or quartzite. The rocks may be typical pebbly mudstones (tilloids) or may form densely packed layers and lenticular bodies.

Ball and pillow structures and load convolutions were observed at the base of certain conglomerate or sandstone beds. Cross-bedding and clay gall breccias are not rare. Rhythmic sedimentation frequently is indicated in the sequence of beds and within single laminae.

The Upper Carboniferous formation — the thickness may attain 1500 m — reflects rather unstable conditions. Deposition was rather rapid (load convolutions, thickness of the formation and of single beds). The character of the succeeding beds varies very much. There are features characteristic of flysch and of shallow-water origin. In other parts of Kashmir the formation has yielded horizons containing marine fossils and beds bearing Gondwana plants. There are tuffs and intercalations of trap and tilloids highly suggestive of a glacial origin.

Reviewing the Upper Palaeozoic development we find the rather stable conditions, which have produced the pure shallow-water quartzites of the Devonian Muth Series, increasingly become unstable, culminating in the Upper Carboniferous-Permian volcanism. The Gondwana floras of Kashmir are not the only witness of influences from the southern continent, there are also climatic ones. Though facetted and striated boulders hitherto have not been found in the tilloids, their character suggests glacial origin. The Middle to Upper Permian Zewan Beds are the beginning of a new sedimentary cycle in the course of which the thick Mesozoic sequences were deposited.

1.1.5. The Marbal Pass — Kishtwar Traverse (Pl. 1, 4)

The author proceeded from eastern Kashmir over the Marbal Pass for a traverse of Pangi-Chamba. Pioneer work in these regions has been done by STOLICZKA (1865) and LYDEKKER (1878, 1883). Since these early days few further investigations have been made. MIDDLEMISS & BION (1928) described the Agglomeratic Slate from the Marbal valley and brief account is given in FUCHS & GUPTA (1971). WAKHALOO & DHAR (1971) summarize the results of their recent studies which, however, prove to be less reliable than the descriptions from the pioneer days.

The section to be described follows the regional strike of the Himalayas (NW-SE). The tectonic axis plunges from a culmination in the Chenab valley (ENE Kishtwar) towards the synclinorium of Kashmir. Therefore, and as we descend from the high mountains of Kashmir to the deeply eroded Chenab valley, we cross the Palaeozoic sequence in descending order and enter a lower tectonic unit — the Chail Nappe — at Kisthwar.

We leave the road from the valley of Kashmir at the village Marbal, SE of Wyl (Vailov). Following a tributary stream (Karbuduran) to the Marbal Pass we walk along the SW-limb of an anticline (Fig. 19). MIDDLEMISS & BION (1928) called it the Marbal Valley Anticline.

At the village Marbal Permo-Mesozoic limestones dip SW with 40—50°. Panjal Trap lies NE of the village. It dips beneath the limestones at varying commonly steep angles.

Then the next older formation, the Agglomeratic Slate, is exposed along the trail. It consists of green sandstones, quartzites, pebbly mudstones, conglomerates, diabase, tuffitic slates, etc. Locally boulders up to 50 cm diameter have been observed.

At the junction with a tributary stream from the N (arrows in Fig. 19) a section trough the underlying Fenestella Shales, Syringothyris Limestone, and Tanols was studied (Fig. 20):

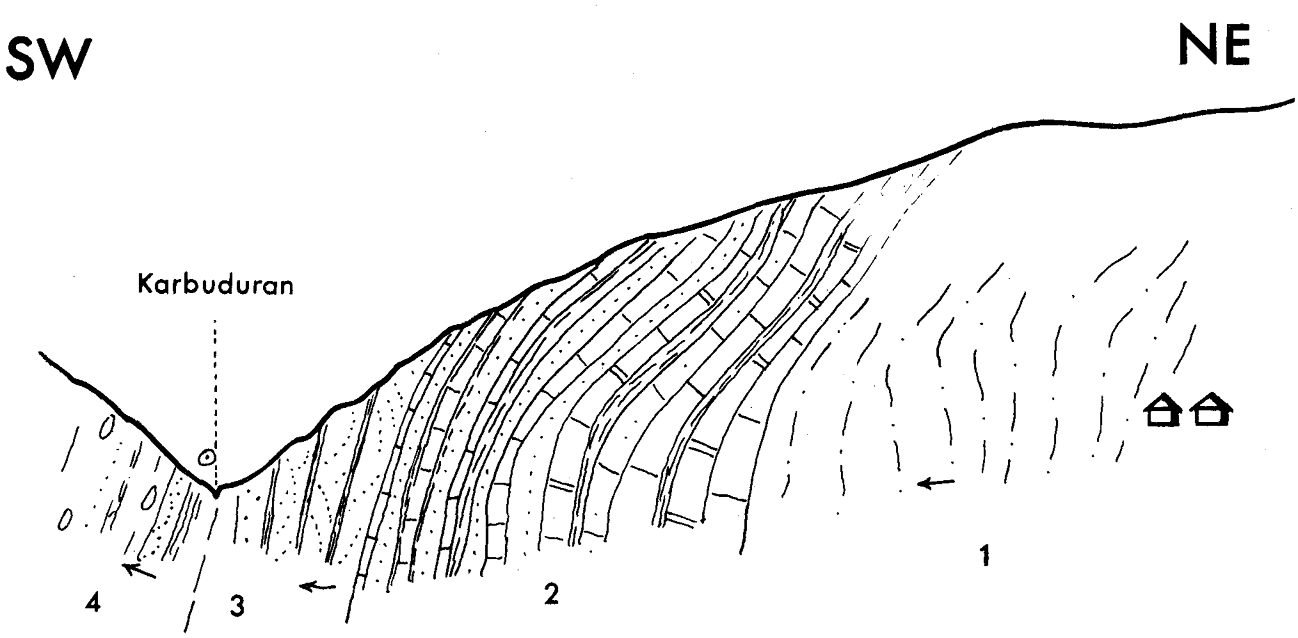
4. Cross-bedded quartzites and dark slates of the Agglomeratic Slate outcrop on the orographically left bank of the Karbuduran (top in SW). Loose blocks of micaceous arenaceous slate contain imprints of large crinoid stems.

3. Massive to thick-bedded, pure quartzite of white to dark grey colour and dark slates form a 40 m sequence. Cross-stratification is very pronounced. Though no fossils were found, from lithology there is not much doubt that this series represents the Fenestella Shales

2. The Syringothyris Limestone consists of well-bedded blue to grey limestones, dolomites, arenaceous carbonate rocks, carbonate quartzites, breccias, sandstones, dark

Fig. 20. Section across the Marbal valley along a tributary stream from the N (situation indicated by arrows in Fig. 19).

1 Tanol
2 Syringothyris Limestone
3 Fenestella Shales represented mainly by quartzite
4 Agglomeratic Slate
Length of section ca. 450 m



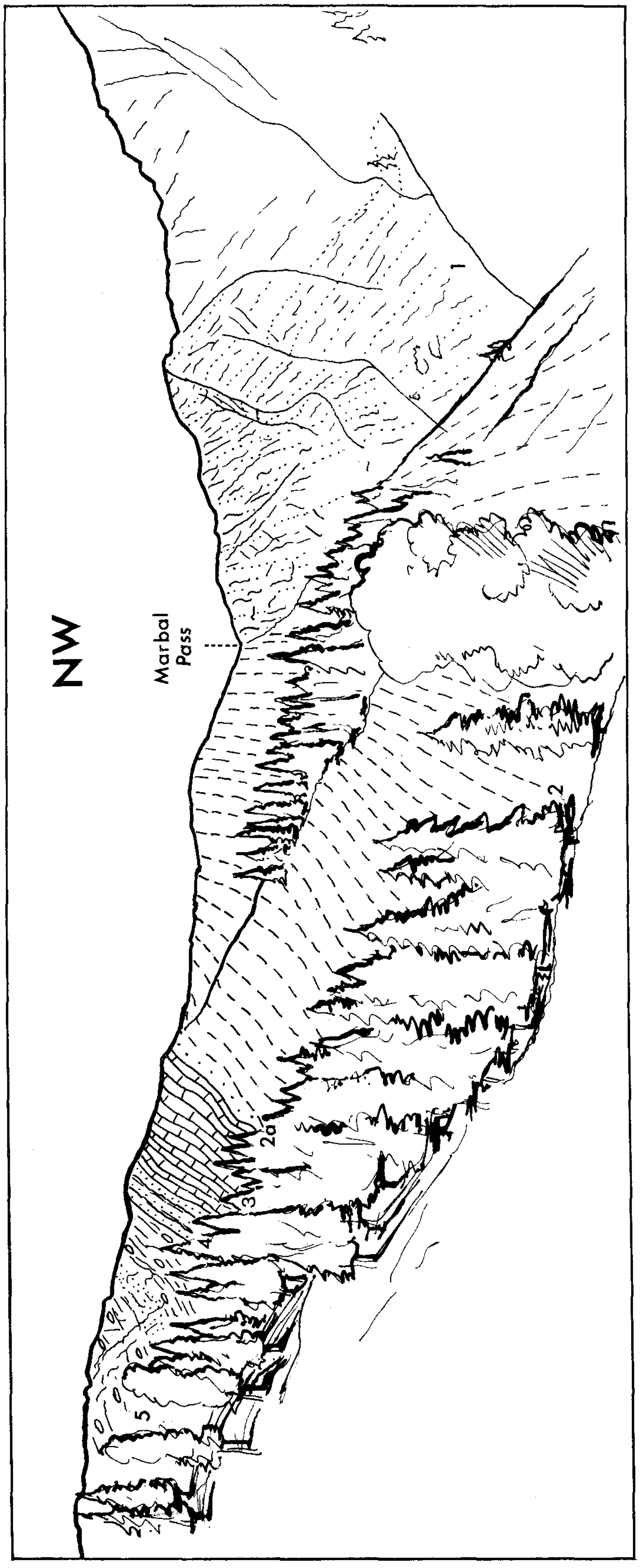


Fig. 21. The south-western flank of the Marbal Valley Anticline in the area of the Marbal Pass, seen from SE.

1	Dogra Slate	3	Syringothyris Limestone
2	Tanols	4	Fenestella Shales (here rich in quartzite)
2 a	Quartzite	5	Agglomeratic Slate

arenaceous shales, and cross-bedded quartzites. Certain beds are full of crinoids, brachiopods, and bivalves; the fossils, however, are not well-preserved. The thickness of the formation is ca. 180 m. The upper 80 meters of it are more arenaceous and grade into the overlying quartzites of the Fenestella Shales.

1. The underlying beds are the Tanols. They consist of light grey to green slates, silty slates with a few dm - layers of sandstone or carbonate sandstone. The rocks are finely laminated and show graded bedding — top to the SW. There is no indication of a stratigraphic break between the Tanols and the Syringothyris Limestone. Middlemiss & Bion (1928) have noted that the Muth Quartzite which is well developed in the next anticline to the NE, is missing (p. 10—11). Probably the Muth Quartzite is replaced by the argillaceous flysch-like facies of the Tanols.

Farther up the Karbuduran river there are outcrops of inverted NE dipping Syringothris Limestone. Then the trail enters the Tanols (Fig. 19). The upper Tanols contain layers of quartzite and sandstone, underlain by predominantly silty slates and siltstones. Graded bedding, laminations, load convolutions, granulated s-planes, etc. give the formation a flyschoid character. At the ascent to the pass the NE dipping silty slates contain arenaceous layers.

The ridge of the Marbal Pass consists of the Tanols S of the pass, and dark grey arenaceous slates and thin-bedded quartzites, N of the pass (Fig. 21). Blocks from the N consist of quartzite, phyllite, and arenaceous micaceous slate. They are irregularly interbedded and show flaser structures and burrows. These rocks strongly call of the Cambro-Ordovician of NW-Kashmir.

Fig. 21 shows the Marbal Pass seen from SE. The trail descends from the pass along the Tanol-Syringothyris Limestone boundary, and I found a clear sedimentary transition:

At the top the Tanols become rich in quartzite and sandstone layers (ca. 2 m). Light coloured silty slates, ferruginously weathering carbonate layers, light quartzite and carbonate quartzite alternate in a dm-rhythm.

This horizon is succeeded by light arenaceous dolomite and limestone and dark blue limestone with layers of intraformational breccia. This alternation — typical Syringothyris Limestone — contains badly preserved crinoids, brachiopods, and gastropods. The thickness of the Syringothyris Limestone here is about 80 to 100 m.

The quartzite zone on top of the Syringothyris Limestone represents the Fenestella Shales — fossiliferous slates have been found in the talus W of the pass.

The overlying Agglomeratic Slate contains many and rather thick zones of pure quartzite.

The higher parts of the mountains in the S are formed by Panjal Trap, as shown by fallen blocks and boulders in the streams.

It is significant that in the above section the Syringothyris Limestone develops from the Tanols without any sign of a break in deposition. Thus in the Marbal area the Tanols, which replace the Muth Quartzite, range up to the base of the Lower Carboniferous carbonate formation. The existence of both, an argillaceous and an arenaceous facies of the Devonian, within a relatively small area is unquestioned.

If we descend the valley in SE direction the trail (on the right side of the valley) for long distances runs in the Tanols. The orographically left slopes consist of the Early Palaeozoic slates and quartzites.

At a bend of the river steeply dipping Syringothyris Limestone somewhat reduced, and the quartzites and black slates of the Fenestella Shales come down to the bottom of the valley.

The Tanols become more sericitic towards SE and are cut by dioritic dikes (Panjal Trap?). The slates contain psammitic beds.

At a bend of the river W of Singhpur there is an outcrop of vertical Fenestella Shales (ca. 120—150 m). The series of thick-bedded, white to black quartzites and intercalated black, arenaceous, micaceous slates contains layers full of fossils. Dr. V. J. GUPTA kindly has given the following identifications:

Syringothyris lydekkeri DIENER
Spirifer trigonalis MARTIN
Chonetes sp.
Protoretepora cf. *ampla* LONSDALE
Fenestella aff. *plebeia* M'COY

This seems to be the fossil locality mentioned by LYDEKKER (1878, p. 57—58).

In the above series there are a few limestone beds on the trail to Singhpur but the Syringothyris Limestone seems to be missing or to be highly reduced. From the outcrops between Singhpur and the Marbal Pass it seems that Syringothyris Limestone and Fenestella Shales would at least partly replace each other.

Before we reach the village Singhpur we leave the Upper Palaeozoic formations and the Tanols and get into the thick, monotonous Early Palaeozoic sequence: The series weathers in more irregular pieces and blocks compared with the thin- and even bedded Tanols. The colours are grey, green, dark dirty grey, or rarely black. Slates, siltstones interbedded with quartzite, greywacke, or sandstone are prominent. There are very rare dark carbonate beds which show ferruginous weathering. Characteristic are burrows (of annelids?) which frequently disturb or obliterate the bedding planes. Such rocks are common in the Cambrian of NW-Kashmir. The s-planes are often phyllitic.

Towards the village Chattura the rocks strike NNW-SSE and are nearly vertical. Thus following the valley towards SE we get into lower parts of the monotonous rock complex. Now the slates predominate. Grey to black, green slates, siltstones with layers of fine-grained sandstones are the country rocks.

E of Chattura the rocks strike N-S and are vertical. They are tightly folded and sheared. B-axes frequently trend SW-NE. Parallel with the intensive deformation the series becomes more and more phyllitic.

The series of black phyllites (several 100 m) which are already graphitic steeply dip towards E.

The first grains of garnet — of a few mm size — appear in the phyllites ca. 3 km SE of Chattura. Then steeply dipping granite-gneiss crosses the valley. No higher metamorphosed rocks such as paragneiss or contact rocks were observed. The granite-gneiss is in direct contact with the phyllites. It is a light, homogeneous, medium - to coarse - grained orthogneiss containing both micas. The strong deformation has produced flaser - and augen structure. The granite-gneiss contains a few lenses of amphibolite or paragneiss (up to m-size).

Under the microscope the main constituents are potassium feldspar (patch perthite), oligoclase-albite, quartz, a pale green-brown biotite, and muscovite. Sericite, calcite, chlorite, and epidote-clinozoisite are of secondary origin. The strong deformation is clearly visible also in the slide (broken crystals, bent micas, mortar structures, etc.).

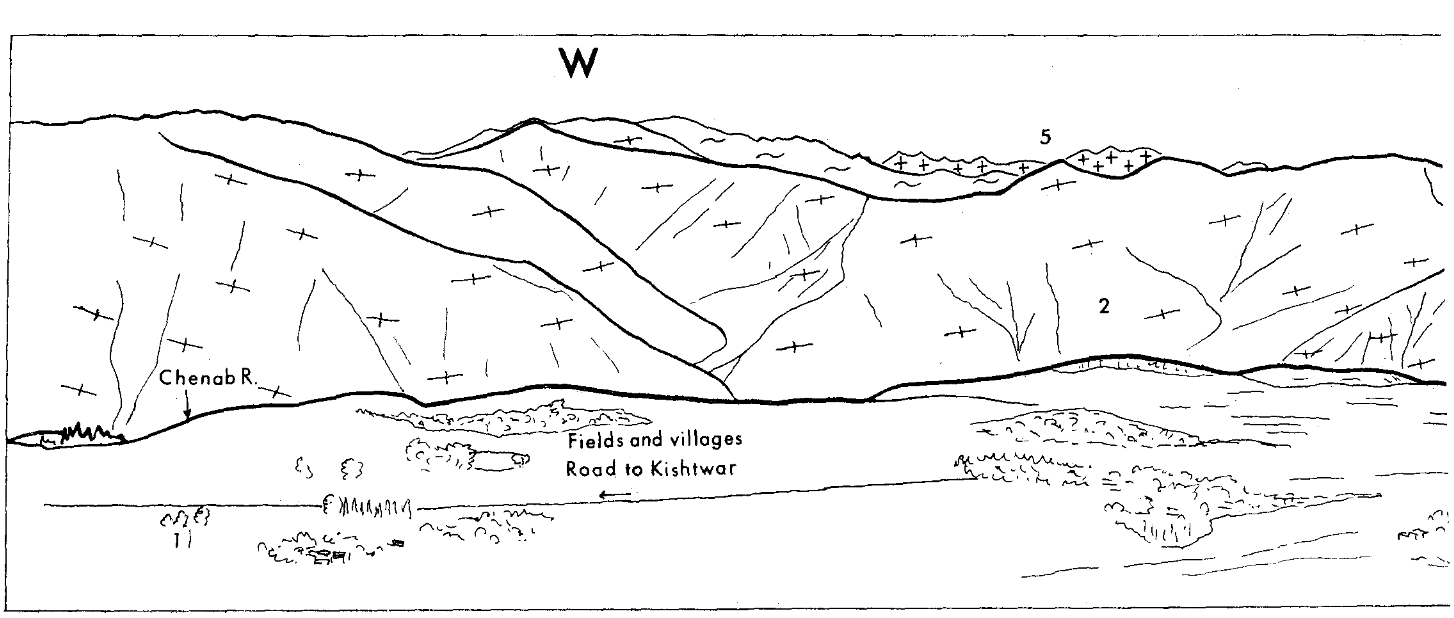
The granite-gneiss resembles those of the Pir Panjal Range what already has been noted by LYDEKKER (1878, p. 57).

To the E the granite-gneiss ca. 800 m thick is succeeded by grey phyllites with psammitic layers. Relictic cross-bedding has been observed in the quartzitic beds. The relative quantities of phyllite and quartzite are approximately 7 : 3. One lense of amphibolite only 30 cm thick was found. Porphyroblasts of garnet (1—4, rarely 7 mm) and biotite (up to 1 mm) indicate increased alteration as we get into deeper parts of the complex. Biotite prefers the psammitic layers whereas garnet is restricted to the phyllites, which commonly are microfolded. The B-axes plunge SW, the schistosity is steeply dipping WSW.

A zone of thick-bedded, pure quartzite ca. 130 m thick crosses the valley NW of Moghulmaidan. Cross-bedding is common. The vertical beds strike NNS-SSW.

Further to the E phyllites predominate again, but there are also psammitic beds and rare amphibolites. Gradually the crystallinity increases, the phyllites become phyllitic mica schists and garnetiferous muscovite-biotite schists (between Moghulmaidan and the junction of the Satgal river). Beyond the junction the psammitic layers in the mica schist become gneissose. They are fine-grained two mica-plagioclase gneisses rich in quartz, which may contain small garnet. The flakes of brown biotite are nearly free of post-crystalline deformation. Only locally retrogressive alterations (chlorite) were found.

Near the village Leitbet there are a few calc-silicate layers in the above mica schist-paragneiss series.



Beyond the village the series is much folded along tectonic axes dipping SSW.

There are conspicuous layers and lenses of calc-silicate rocks in the paragneiss near the junction of the river followed with the Maru Wardwan river. The rocks dip SW with medium angles, the tectonic axes dip SSW to SW. A short distance down stream the Maru Wardwan river the first occurrence of kyanite was noticed. From here to Brinswar the metamorphic complex consists of coarse muscovite-biotite schists and muscovite-biotite-plagioclase gneisses which may contain garnet or kyanite (of several cm length), fine-grained light grey two-mica gneisses, and subordinate layers of amphibolite and lime-silicate rock. The two-mica gneisses are rather rich in feldspar, — oligoclase and microcline; the latter being stable in contact with muscovite. The biotites are of brown colour. The rocks contain small quantities of epidote-clinozoisite.

From Brinswar to the Chenab river the alternation of rather coarse-grained mica schists, mica rich paragneisses, and fine - to medium - grained feldspar rich gneisses contains pegmatoid augen and lenses up to 50 cm thickness. These quartz — feldspar mobilisations also may contain coarse aggregates of kyanite. Dip is 40—65° SW to WSW, and the B-axes plunge SW.

A light orthogneiss body 100—200 m thick is intercalated in the above series on the E-side of the Chenab S of the bridge. The medium to coarse-grained rock consists of microcline partly perthitic, oligoclase-albite, quartz, muscovite as prevalent mica, biotite, and accessories such as apatite. There are layers and lenses of tourmaline bearing pegmatoids (Fig. 22 on Pl. 8).

On the ascent from the river to Kishtwar we get into the paragneiss complex again, which contains a few calc-silicate (dm) and amphibolite (1 m) layers.

The alluvial deposits on the terrace of Kishtwar hide the vertical fault, which separates the described crystalline complex from the Chail rocks exposed in the ridge E of the town. These gently N to NNE dipping rocks show alterations of the greenschist facies. Surrounded by a higher metamorphic complex (amphibolite facies), the Chails form a tectonic window. Though there is a thrust plane between the Chails and the overlying Crystalline the two units at Kishtwar abut against each other along a fault (Fig. 23).

R e v i e w a n d C o n c l u s i o n s :

The route described has revealed a continuous section through the sequence of the Crystalline Nappe from the Upper Palaeozoic to the base of the high grade metamorphic complex. The existence of the Chail window of Kishtwar shows that the Kashmir Synclinorium and its basement actually form a nappe. This nappe is overthrust for at least 60 km. Thus WADIA's views have been confirmed.

As in so many sections the metamorphism of the crystallines gradually dies out in the overlying Palaeozoic succession. From the thick basal beds of the latter, the Precambrian to Lower Palaeozoic geosynclinal deposits (Dogra Slates — Silurian), a large part of the Crystalline was formed. The enormous thickness — the phyllitic series may attain about 4000 m and a similar amount seems realistic for the high grade metamorphosed complex., — probably is the result of folding.

I should like to point to the fact that the thick pile of gneissic rocks is missing in the Banihal and the Gulabgarh sections of the Pir Panjal Range. Also the Dogra Slates are missing in the latter section. This has a parallel in Chamba and shall be discussed later.

The metagranites and granite-gneisses of the Pir Panjal are also present in the area described. The granitic body in the phyllites W of Moghulmaidan, and the intrusions in the Chails of the Kishtwar Window.

It is interesting that the folds in the sedimentary complex show a clear NW-SE axis, whereas in the underlying metamorphics NE-SW or NNE-SSW axes predominate, which is an instance of „Stockwerktektonik". B perpendicular to the regional strike is rather frequent in the Crystalline and the Chail Nappes (GANSSER, 1964, p. 249, 250; FUCHS & FRANK, 1970, p. 96). The regional B changes to a transverse B around Chattura. Though the rocks are highly deformed there and the steep beds may even show eastern dip, there is no sound reason to assume the Crystalline to be thrust over the sedimentaries of the Kashmir Synclinorium

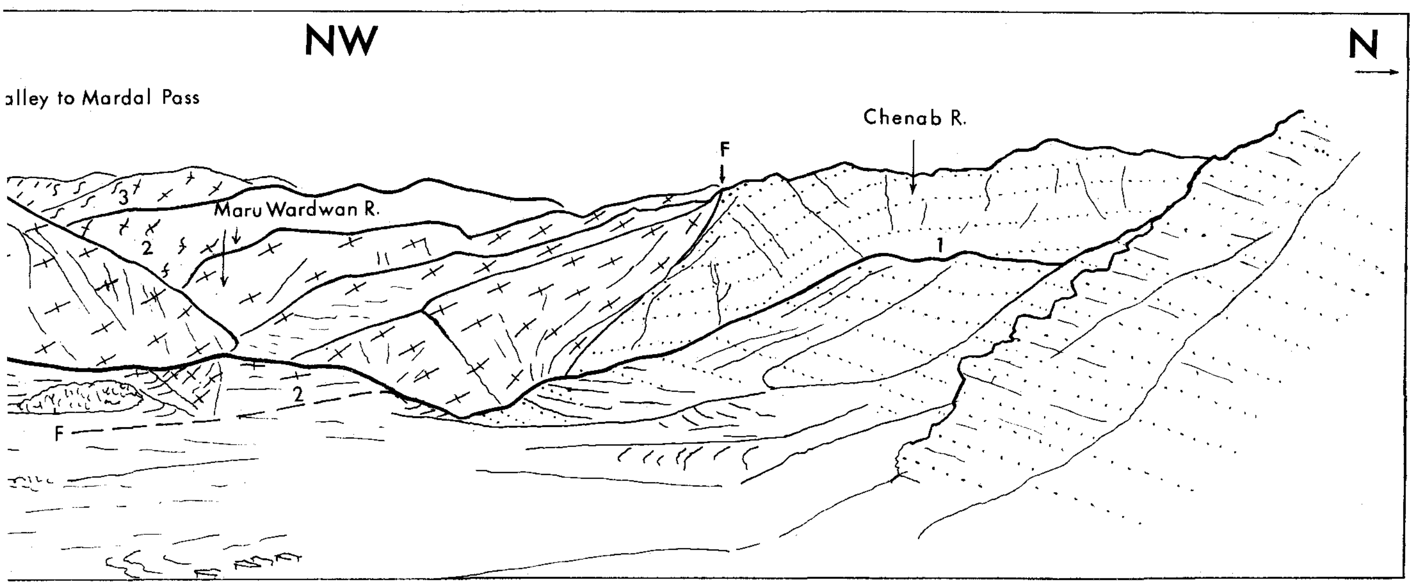


Fig. 23.
View from the Chenab valley at Kishtwar towards NW to Kashmir
1 Chail quartzites abut along fault (F) against
2 ortho- and paragneisses of the Crystalline
3 mica schists
4 Dogra Slates
5 Panjal Trap

(Wakhaloo & Dhar, 1971, p. 126). The steepening of the beds at Chattura is of a flexure type which has warped up lower and more altered rocks. I like to point to the fact that Wakhaloo & Dhar erroneously designated the whole sequence from the Agglomeratic Slate down to the Dogra Slates as "Agglomeratic Slates". The cited paper is inconsistent in many respects, e. g. regarding the "Kishtwar Thrust". The Shalimar (Chail) quartzites are not thrust onto the Crystalline but the reverse is the case and the mylonitic rocks are related with the fault, which separates the two units at Kishtwar. Thus the terms "Chattru" — and "Kishtwar Thrusts" should be abandoned.

1.2. Kishtwar — Pangi — Chamba (Pl. 1, 4)

The relation of the Kashmir sequence to the Kishtwar rocks has been described in the preceding pages. The section has led us into the region adjoining Kashmir in the SE. I am going now to continue the description of our route from Kishtwar upstream the Chenab or Chandra — as it is called in its upper course.

1.2.1. The Kishtwar — Kilar Section

The Kishtwar Window is exposed for 38 km linear distance along the Chandra valley. Its rocks, Chails and granitic intrusions, dip beneath the Lower Crystalline Nappe at Atholi, which in turn is succeeded by the thick highly metamorphosed gneiss complex of the Upper Crystalline Nappe.

The ridge E of Kishtwar is formed by gently N to NE dipping rocks of the Chail Formation (B plunges NNE). There is a conspicuous 500 m zone of pure very fine-grained quartzite. The colours are snow-white, yellowish, a very light grey, and green. On s-planes there are films of sericite and rare fuchsite.

The quartzites are overlain by an alternation of quartzite, grey and green phyllite, sericite-chlorite schist, greenschist, and diaphthoritic augen gneiss. For the latter the possibility of being an arkose is excluded by microscopic data. Porphyroclasts (several mm) of plagioclase, potassium feldspar, and quartz are surrounded by a matrix consisting of streaks of mortar quartz, sericite-muscovite, epidote-clinozoisite, green-brown biotite, chlorite, and sphene.

This series is also met along the jeep road at the bend of the river N of Kishtwar. In addition there are conglomeratic layers in the quartzite. The components — mainly quartzite — are elongated to lenses of 8 × 1.5 cm. The rocks dip NE at medium angles, B plunges NNE.

Quartzite, conglomerate-quartzite with cobbles up to dm-size, dark grey, green phyllites, and chlorite schists form the country rock upstream from the bend (near the village Dul).

This alternation apparently also builds up the orographically right side of the valley. A huge recumbent fold is visible from afar (B plunges NNE with 20—30°).

Metadiabases ESE of Dul show the characteristic lithology of the Chail metabasites found throughout the length of the Himalayas. They still exhibit ophitic structures. The original minerals, however, are entirely replaced by albite, sericite, calcite, chlorite, epidote-clinozoisite, sphene, and ore.

Beyond Naghre bridge near the village Nos the phyllites are interbedded with layers of fine-crystalline, light grey limestone showing ferruginous weathering.

Then the phyllites pass into a series of dark to light grey, greenish laminated slates and siltstones. Flaser structures and graded bedding give a more flyschoid character to this dark series.

Again green Chail phyllites, psammite schists, and quartzites follow near the village Badherna. Greenschists are found in the Chails as in the above dark series. The latter may represent a dark flyschoid development in the Chail Formation or the series are Simla Slates forming the core of a recumbent anticline. The later seems more probable as similar limestone intercalations in the passage zone from Simla Slates to Chails have been observed several times (Fuchs & Frank, 1970, p. 32, 33).

Typical Chails and the dark laminated slates crop out repeatedly. The rocks are strongly folded (B plunges N with 30—40°, and the s-planes dip NNE with 20—40°).

These rocks are overlain by 800—1000 m of granite-gneiss ca. 1/2 mile before the village Kalahar. The thick-bedded to massive rocks dip ENE with 35—45°, B plunges NNE with 35°. It is a coarse-grained porphyric and rather homogeneous metagranite. Idiomorphic and twinned phenocrysts of potassium feldspar (1—1.5 cm) are rather densely packed. The rock contains both micas, however, they are somewhat subordinate. There are sporadic biotite patches of cm-sizes. The rock is affected by cataclasis.

At the village Kalahar the granite-gneiss is overlain by Chails, which in higher parts of the slope seem to join with the underlying Chails. Thus the granite-gneiss apparently forms an anticline.

The Chails show varying dip, however, the NNE direction predominates, dip angles being 20—30°. Some distance E of the village again granite-gneiss is coming up from beneath the Chails. It is somewhat tectonized augen gneiss — the feldspar augen reach 3 cm.

The trail going along the southern side of the valley crosses the boundary of the gneiss several times. The overlying gently dipping Chails are intertonguing with the gneiss towards the E. The boundary is highly sheared — no contact metamorphism is observable. The granite-gneiss, however, is darker and more fine-grained near the contact.

Farther E there are also non-porphyritic, medium-grained, massive two-mica metagranites.

At another intercalation of Chails the intrusive nature of the granite is unquestionable. Subparallel to s the country rock is invaded by aplitoid, pegmatoid, or quartz sills. The phyllites are rich in biotite (pale green-brown) and fine tourmaline crystals near the contact. They may form m-thick inclusions in the granite. All the rocks are affected by the phyllitic metamorphism (sericite films etc.), which was related with shearing and folding along axes plunging NNE to NE with 20°. That means that the intrusion of the granite preceeded the Alpine deformation and metamorphism.

Farther upstream we find fine- to medium-grained, massive as well as coarse, porphyric metagranite. The latter under the microscope show the hypidiomorphic magmatic structure very well. Microcline forms partly broken phenocrysts. It contains parallel orientated idiomorphic plagioclase inclusions. The plagioclase (albite-oligoclase) is partly "filled" by sericite and clinozoisite. The quartz is healed, showing undulating extinction rather rarely. It forms mortar zones along fractures in feldspar. There is muscovite and green-brown biotite containing some sagenite. Fine aggregates of epidote-clinozoisite, sphene, encrusting grains of ore, sericite, some calcite and chlorite are of post-magmatic origin. The cataclasis is obvious, but it has not obliterated the original magmatic structure.

Also the fine-grained variety shows the preserved hypidiomorphic structure. Particularly the albite is idiomorphic. Except the outer rim they are filled with microlithic sericite and clinozoisite. This indicates that plagioclase was more basic before the alteration in greenschist facies. Epidote-clinozoisite, sericite, sphene, etc. are of metamorphic origin. The muscovite and greenish biotite are primary probably, the colour of the latter, however, is caused by the later alteration.

At the bend of the river the trail crosses a syncline of phyllites and pure quartzites of the Chail Formation. There are aplitoids, pegmatoids, and quartz dikes or sills, which have been torn out to lenticular bodies of dm - to m - thickness. B-axis of the syn-metamorphic deformation is NNE plunging with 20—45°.

With NNW dipping s-planes the granite-gneiss comes up again E of the syncline. Phenocrysts of potassium feldspar (2 cm) give the rock a porphyritic character. Here the granite is rather hybrid — it contains basic nodules and numerous intercalations of the country rock. Fig. 24 (on Pl. 8) shows a discordant contact of the metagranite against Chail phyllites containing lenses of quartz. The granite is fine-grained in a ca. 30 cm thick marginal zone.

Commonly there is no contact metamorphism, but, there is a higher content in biotite or feldspar metablastesis (up to 5 mm) locally.

Then medium-grained massive types prevail (Fig. 25 on Pl. 8). There are subordinate developments of very coarse porphyritic varieties — potassium feldspar reaches 5 cm lengths. There are no sharp boundaries to the surrounding medium-grained rock which contains a few sporadic phenocrysts. Small dikes of pegmatite (± tourmaline) cut the granite.

For several km both slopes of the Chandra valley are formed of granite of the types described. Grade of hybridity and deformation varies in zones. The rocks dip NE at medium, locally, steep angles; B plunges N to NNE.

Chail phyllites and quartzites overlie the granite complex. They are invaded by dikes of pegmatite and quartz. NE dipping quartzites may be followed to the village Kidshaihi.

E of that village a conspicuous dark formation overlies the light coloured Chails. The series has large extension W and N of Atholi. The thickness of ca. 1000 m seems to be caused by tectonics. The rocks are vertical or dip E to ENE at steep to medium angles (Fig. 26).

The formation consists of black to dirty grey, arenaceous phyllitic schists, graphitic phyllites, grey to silvery, phyllitic mica schists, layers of white to yellowish, fine-grained quartzite, dark, fine-grained graphitic calc-mica schists and fine-crystalline marble. The phyllites and mica schists, which are frequently microfolded, prevail in that series. The growth of garnet is often observed; muscovite and biotite are stable. Replacement of biotite by chlorite is proof of local regressive metamorphism.

Efflorescence and rusty weathering are common in the dark rocks.

The described rock assemblage is lithologically identical with the Jutogh Formation of Simla or the rocks of the Lower Crystalline Nappe of W-Nepal (Pilgrim & West, 1928; Fuchs, 1967; Fuchs & Frank, 1970). The tectonic position between the Chails and the overlying high grade metamorphosed complex is the same in all the instances cited. It is surprising how far many of the stratigraphic-tectonic units may be followed, without changing their character.

The unit is much deformed. A conspicuous break in the grade of metamorphism is neither at the base nor at the top. The underlying Chail rocks are altered in greenschist facies. Biotite was observed only near the granite contacts. In the rocks of the Lower Crystalline Nappe at Atholi biotite is generally present. The grade of alteration is greenschist facies to lower amphibolite facies, whereas the metamorphism of the overlying series is clear amphibolite facies. Thus one could envisage a gradual increase of metamorphism. The constant character of the rock assemblage, its continuity, and the fact that there are

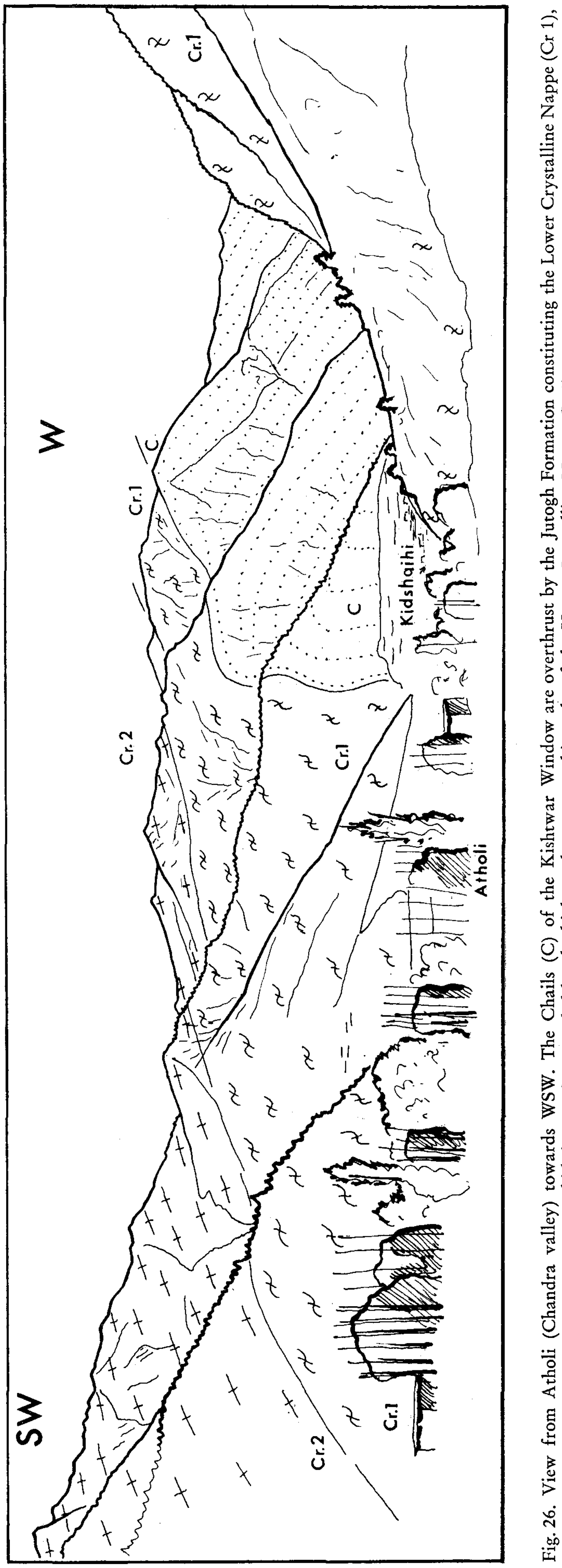


Fig. 26. View from Atholi (Chandra valley) towards WSW. The Chails (C) of the Kishtwar Window are overthrust by the Jutogh Formation constituting the Lower Crystalline Nappe (Cr 1), which in turn is succeeded by the high grade metamorphic rocks of the Upper Crystalline Nappe Cr 2).

clear indications of thrusting at its base and top in other parts of the Himalayas are reasons why we call the unit Lower Crystalline Nappe.

Relics of sillimanite in rocks immediately overlying the Lower Crystalline Nappe show that the apparent gradations are caused by regressive metamorphism (see below).

E of Atholi we get into the Upper Crystalline Nappe a thick complex of highly metamorphosed rocks. Two-mica-plagioclase gneiss and microcline-augen gneiss layers are intercalated in two-mica schists. Garnet is rather fine-grained (mm-size). A very significant observation was made in one slide of these rocks. Needles of sillimanite are enclosed in larger graines of apatite in a rock which otherwise is free of minerals such as sillimanite and kyanite. Apart from locally chloritized garnet the rocks show no regressive alterations or postcrystalline deformation. This is a characteristic of the rocks of the Upper Crystalline Nappe. From the above observations it follows that there was an earlier high grade metamorphic crystalline (sillimanite) which later was adapted to lower grades of the amphibolite facies (richness of muscovite). Therefore it is not possible to conclude from the common absence of relics that the Himalayan Crystalline is monometamorphic.

The dip of the rocks is ENE to ESE at medium angles, B plunges NE. Beyond the bridge the trail, now running on the orographically right side of the river, crosses coarse-grained garnet-mica schists (garnet 2—8 mm) alternating with fine-grained two-mica-plagioclase gneiss. The rocks contain kyanite and staurolite.

Main constituents are quartz, oligoclase, brown biotite, muscovite, kyanite, and staurolite; there are lots of small rutile crystals; apatite, ore. Chlorite replaces garnet and biotite, in certain zones.

Then calc-silicate rocks, and coarse-grained phlogopite marbles are found in the above series. These intercalations may attain thicknesses of several tens of meters.

Above the carbonate zone the coarse-grained garnet-kyanite-staurolite-mica schists and — gneisses are interlayered with aplite-gneiss bearing tourmaline, and fine-grained, light, two - mica gneiss. Pegmatoid lenses are numerous. Nebulitic migmatites (Fig. 27 on Pl. 9) and biotite-augen gneisses (Fig. 28 on Pl. 9) become important intercalations. They form ill-defined zones without sharp boundaries, up to a few tens of meters thick. Thus the series gets a distinct migmatitic character. Even ptygmatic folding has been observed (Fig. 29 on Pl. 9). But the paragneisses and mica schists prevail.

The figures 27—31 (on Pl. 9 and 10) show the most common migmatitic structures observed in this complex. In the light of these observations — and they are alike those from the Nepal and Bhutan crystallines (Fuchs, 1967, fig. 25, 26; Fuchs & Frank, 1970, fig. 16; Bordet et al. 1971, p. 73, 254; Gansser, 1964, fig. 61, 62, 64, 85 to 89) — it is surprising that Frank (1973) denies the importance of migmatites in the Himalayan Crystalline.

Under the microscope the composition of the migmatitic gneisses is rather simple: microcline, oligoclase, quartz, muscovite, brown biotite, and small amounts of garnet, apatite, zircon etc. Sericite and chlorite occur as local replacement products from feldspar and biotite respectively. The augen, lenticles, and veinlets are formed by microcline, or microcline — oligoclase —quartz aggregates.

W of the village Sohal the paragneisses in the above series contain much sillimanite.

In the slide the rock consists of antiperthite, quartz, biotite, muscovite, sillimanite, and garnet. Kyanite a mineral so frequent in the complex is missing in those rocks. Part of the muscovite shows myrmekitic intergrowth with biotite, plagioclase, etc. and encloses sillimanite. These paragneisses seem to have reached the highest grade of the amphibolite facies (Winkler, 1965, p. 91) and the muscovite probably is of younger age.

Fig. 32(on Pl. 10) shows the irregular nebulitic nature of the coarse-grained augen gneiss which is associated with the above paragneiss at Sohal. Several times I have found that these augen gneisses, which grade into the coarse garnet-kyanite-flaser gneiss with its characteristic pegmatoid lenticles, are older than the fine-grained migmatitic gneisses (Fuchs, 1967, fig. 25, 26; Fuchs & Frank, 1970, p. 47, fig. 16). As these younger migmatites are commonly parallel to the former gneisses the age relation can be found only by subtle observation. My view is contested by Frank (1973). At Sohal, however, I have found clear evidence that the finer-grained migmatitic gneiss is younger than the flasery paragneiss and augen gneiss. Fig. 33 (on Pl. 10) shows the latter finger out in the surrounding finer-grained and more homogeneous gneiss. Here it can be demonstrated beyond doubt, that the fine-grained gneiss cuts the foliation of the older gneisses. It has had higher mobility and thus shows an intrusive behavior, which is inconsistent with the view that the fine-grained gneiss poorer in mica represents former psammitic layers. The time interval between the formation of the named gneisses, however, is uncertain.

Beyond the named village the dip of the rocks changes from E to NNE and N. The B axes plunge ENE. Again we find the garnet-kyanite paragneiss, and various migmatitic gneisses. Amphibolite layers and lenses of small thickness are very rare intercalations in the gneiss.

Nebulitic augen granite-gneiss has vast extension in the gorge-like course of the Chandra valley upstream from Sohal. The irregular character of these rocks is illustrated by Fig. 34 (on Pl. 10).

W of Tiari fine-grained migmatitic gneiss and garnet-kyanite flaser gneiss are overlying the above augen gneiss complex. Dikes of pegmatite and aplitoid up to 15 m thickness are partly folded, partly they cut across the folds and foliation of the gneiss. The rocks which contain garnet, tourmaline, and plates of muscovite have been formed in a rather late stage of the migmatization. The folds cut by these dikes plunge ENE. At the villages Tiari and Ishtiari major folds are visible in both slopes of the valley.

From the named villages to Darwas we find garnet-kyanite-two-mica gneiss with the pegmatoid lenticles, nebulitic migmatites, aplites, pegmatites, and rare amphibolite lenses. At Darwas the ortho material prevails in the migmatitic series.

A light coloured fine- to medium-grained granite-gneiss E of Darwas shows under the microscope: Microcline, oligoclase (antiperthite), and quartz form a granoblastic plaster; brown biotite, muscovite; apatite and zircon are accessories.

From Darwas to Kilar and in the surroundings of that village we find the garnet-kyanite paragneiss, fine-grained migmatitic gneiss, augen gneiss, aplite, and pegmatite (Fig. 35 on Pl. 11).

The dip of the rocks is SW to SSE from Ishtiari to Kilar; B plunges WSW or ENE.

PLATE 9

Fig. 27. Nebulitic migmatite; at the bend of the Chandra valley SE of Atholi.

Fig. 29. Ptygmatic folding of an aplite veinlet in migmatite; S of the bend of the Chandra valley SE of Atholi.

Fig. 30. Fine-grained migmatite with lenses and layers of pegmatoid; S of the bend of the Chandra valley SE of Atholi.

Fig. 28. Augen gneiss; S of the bend of the Chandra valley SE of Atholi.

PLATE 9

Fig. 27

Fig. 28

Fig. 29

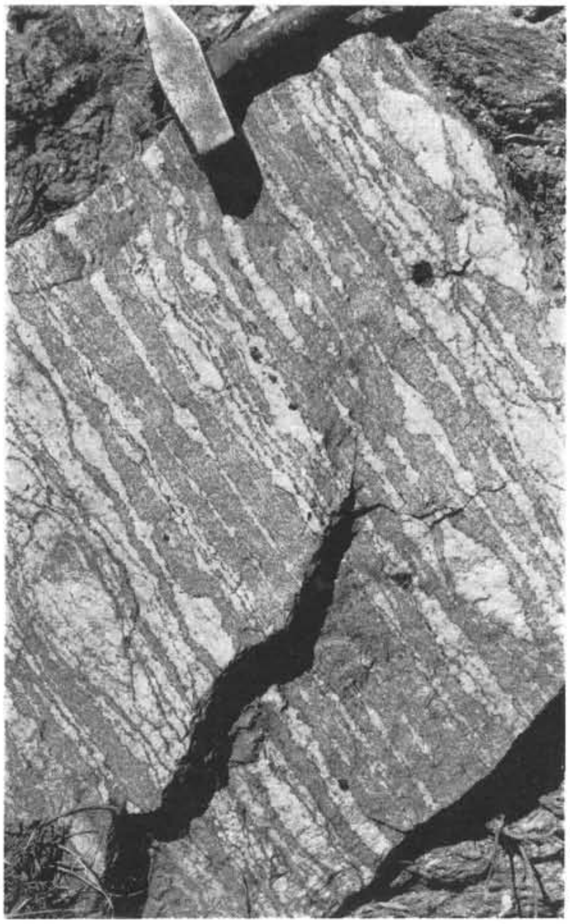


Fig. 30

At Kilar we turned to the S and left the Chandra valley.

Review: From descriptions given by LYDEKKER (1878) I was able to draw some of the continuations of the rock units found along our route. Also his observations concerning dip etc. are put into our map (Pl. 4). These early data proved to be very useful.

The Kishtwar Fault continues to the village Krur where it crosses the Wardwan river. The characteristic quartzites of the Chails from Kishtwar strike to Krur and are again found around Hanza (LYDEKKER, 1878, p. 52). The north-western end of the Kishtwar Window — LYDEKKER's anticlinal axis — seems to be near this village. The strong contortion at Lopar and the low NE dip suggest that the thrust contact against the overlying crystalline is not far. The massive and granitoid gneiss in the area Lopar-Krur, doubtless, is the continuation of the granite intrusions in the Chails.

We have no information about the southern extension of the Chail window. In NW-SE direction it measures ca. 45 km. The importance of the existence of this window for the interpretation of the structure of the region Kashmir — Chamba has already been stressed. In my 1967 paper I advanced the view that the Chail Nappe — this important structural element, present throughout the length of the Himalaya — might be missing in the farthest NW (p. 131). My recent studies in the Pir Panjal, Kishtwar, Pangi, and Chamba clearly revealed the existence of the Chail Nappe in a characteristic form. A new element, however, are the intrusive granites, which I do not know from Nepal. Granite intrusive in the "formations of Nawakot" referred by BORDET et al. (1971, p. 195—196) may belong to that group of granites. But immediately W of Nepal they make their first appearance in Kumaon *). Recent age determinations by JÄGER et al. (1971) have given an intrusive age of 500 ± 100 m. y. for the Mandi Granite which belongs to that group of granites.

The characteristic rock assemblage of the Lower Crystalline Nappe, present in so many Himalayan sections, is well-developed at Atholi. It is missing at Kishtwar as it is cut out by the Kishtwar Fault.

The high grade metamorphosed rock assemblage of the Upper Crystalline Nappe shows the same rock types as in Nepal. Carbonate rocks, however, are very subordinate in the Pangi Crystalline. Here the metamorphics are largely formed from the material of the Haimantas or Dogra Slates — Lower Palaeozoic, predominantly clastic formations. In Nepal the thousands of meters of marble and calc-mica schists are the alteration products from the lower parts of the Dhaulagiri Limestone (FUCHS, 1967).

The tectonic axes plunge NNE to NNW in the Chail window, a direction which, from a few measurements, seems to hold good also for the Lower Crystalline Nappe. In the Upper Crystalline Nappe the B-axes plunge NE to E or WSW.

1.2.2. The Sach Pass — Dalhousie Section

The huge uplift of crystalline rocks of the Zanskar Range of which the gneisses at Kilar are the south-westernmost part separates the Tibetan Zone in the NE from the Chamba Synclinorium (Pl. 1). The latter corresponds with the Kashmir Synclinorium in its rock sequence as in its structure. The section to be described goes from the Chandra valley via Sach Pass to Chamba and the foot hills SW of Dalhousie (Fig. 3). In the Dhauladhar Range we leave the Chamba Synclinorium, which tectonically belongs to the Upper Crystalline Nappe, and get into the underlying Chail Nappe. In the SW-foot of this range we enter the Parautochthonous Unit, which is very reduced.

The Sach Pass section was first described by MC MAHON (1881). Until recent years our knowledge on the geology of Chamba was based on his work (1882 a, b, 1883, 1885). LYDEKKER (1883) in his monograph on the NW-Himalayas also refers to Chamba. A preliminary account is given on the region by FUCHS & GUPTA (1971). New fossil finds are reported by GUPTA & BEDI (1970) and GUPTA (1971).

Along the trail from Kilar to the Chenab bridge and to the valley leading SW to the Sach Pass we find the gneiss complex described in the preceding chapter. The rocks dip S to SSE at low angles. Pegmatite dikes besides muscovite and tourmaline also contain beryl crystals of cm-sizes.

Following the valley upstream towards Sach Pass we cross the sequences perpendicular to the strike and come into higher levels (Fig. 36). The grade of metamorphism decreases rapidly and the gneiss complex grades into mica schists and a phyllite sequence. The transition from the migmatitic complex to rocks in greenschist facies occurs within 800—1000 m vertical thickness. First the augen gneiss and pegmatoid nebulitic migmatites disappear. The fine-grained migmatites and garnet-kyanite flaser gneisses give way to fine-grained, medium - to dark grey two-mica paragneiss and muscovite-chlorite-biotite schists respectively. They still contain small garnets which are frequently in transition to chlorite.

Under the microscope a fine-grained gneiss shows quartz, plagioclase with some sericite, green biotite, muscovite, garnet, chlorite replacing garnet and biotite, apatite, zircon, and ore.

Near the huts Bidarwani (ca. 16 km to Sach Pass) there is a bed of grey marble in the series.

With further decrease in grade of metamorphism the series passes into fine-grained, grey to violet metagreywackes and quartzitic sandstone with layers of green, silvery, and brown phyllite to arenaceous phyllite. There are also dark graphitic layers. Cross-bedding has been observed in the arenaceous rocks.

Between the 14 and 13 km marks (to Sach Pass) the series becomes more arenaceous and light coloured. Fine-to medium-grained sandstone is thick-bedded and of grey, green, brownish, slightly violet colour. These colours recall the Zajur Formation described in chapter 1.1.2. Silvery to greenish, silky phyllites, light quartzitic schists and homogeneous siltstone are interbedded with the sandstone. Garnet has disappeared and biotite becomes very small and confined to certain layers.

This sequence forms a passage zone to the Tanols. These are respresented by a ca. 800 m succession of light green arkose-quartzite, siltstone, and phyllitic to psammitic schists. The rocks are well-bedded, and lamination is not very frequent.

Under the microscope a fine-grained arkose-quartzite is composed of quartz, plagioclase, microcline, muscovite-sericite, chlorite, a few flakes of green-brown biotite, carbonate, and ore. There seem to be two generations of plagioclase, polysynthetic twinned oligoclase which is detrital such as microcline and round untwinned porphyroblasts which have grown during metamorphism. Both contain fine sericite.

*) 1973 I found these metagranites in the Karnali region of W-Nepal.

PLATE 10

Fig. 31. Banded gneiss (left) in contact with coarse-grained flaser gneiss (migmatite) NW of Sohal, Chandra valley.

Fig. 34. Nebulitic augen gneiss; SE of the village Sohal, Chandra valley.

Fig. 32. Nebulitic augen gneiss; W of the village Sohal, Chandra valley.

Fig. 33. Fine-grained migmatite encloses relictic layers („schlieren") of coarse-grained, flasery garnet-kyanite paragneiss. The latter is evidently older. At the village Sohal, Chandra valley.

PLATE 10

Fig. 31

Fig. 32

Fig. 33

Fig. 34

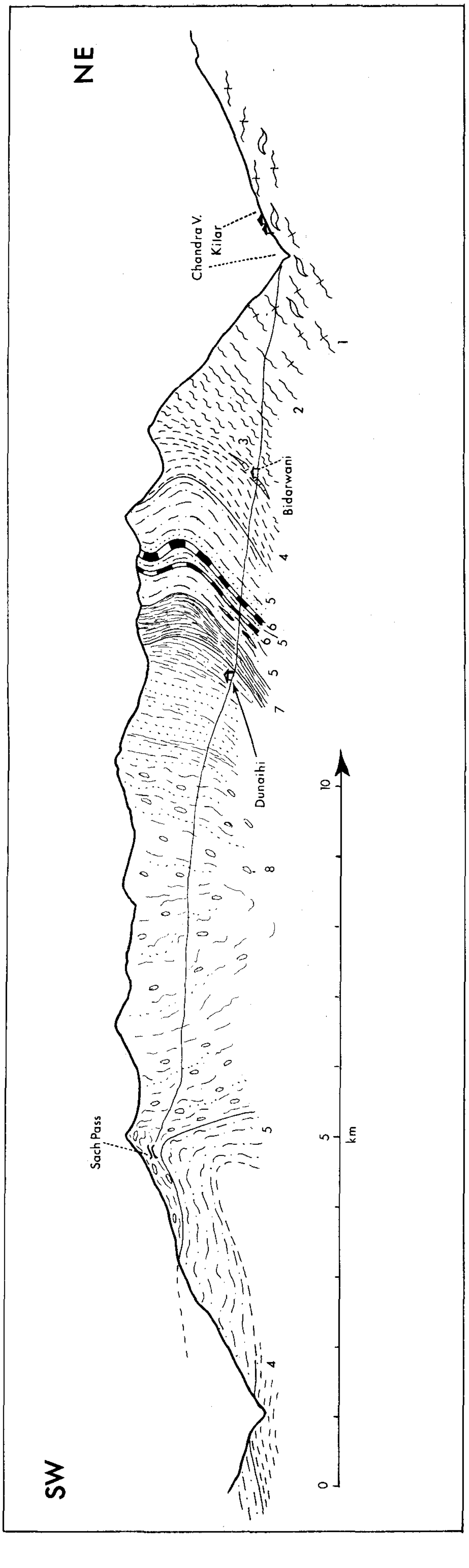


Fig. 36. Section across the Sach Pass Syncline, Pangi.

1 Augen gneiss, migmatites, paragneiss
2 Mica schist with fine-grained gneiss layers
3 Phyllites with fine-grained gneiss layers (marble at Bidarwani)
4 Phyllites and metagreywackes
5 Arkose-quartzites, siltstones, phyllitic and psammitic schists (Tanols)
6 Dark limestones and dolomites (Syringothyris Lms.)
7 Dark slates with layers of sandstone (Fenestella Shales)
8 Agglomeratic Slate.

V. J. Gupta found a few Lower Devonian conodonts in the basal part of the Tanols (Fuchs & Gupta, 1971, p. 85).

The Tanols are followed by a 60 m zone of carbonate rocks (ca. 200 m S from the 12 km stone), subdivided as follows:

At the top of the Tanols phyllitic schists are overlain by a bed of light very hard quartzite (1.20 m). Then come 0.08 m of dark arenaceous carbonate schist and 0.5 m light sericitic schists.

A conspicuous white carbonate layer (0.3 m) weathering to powder passes into a dirty grey, impure limestone (1 m).

It follows a well-bedded alternation of dark, impure limestone and dolomite with breccious layers and light grey dolomite (ca. 15 m). The rocks smell foetid on hammering. There is much dolomitization responsible for finely undulating lamination in these rocks.

A cm - to dm - banded alternation of dark, fine-crystalline limestone and light grey dolomite reaches 30 m thickness. Some beds are lenticular.

Green-grey sandstone and sericitic schists follow (2 m) overlain by 5 m of dark, platy limestone which is banded by slate layers. Then come 1.5 m of dark grey phyllitic slate, which are succeeded by light grey to green phyllitic slates, psammitic schists, and siltstones (ca. 30 m).

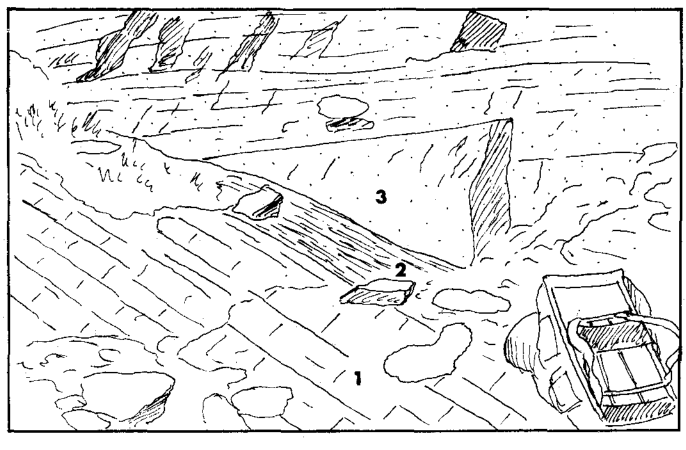


Fig. 37. Contact between Tanol and interbedded Syringothyris Limestones. Description in the text, ca. 11.5 km NE from Sach Pass.

PLATE 11

Fig. 35. Pegmatites unconformably penetrating the paragneiss; NW Kilar, Pangi.

Fig. 39. Schistose tillite, Agglomeratic Slate, ca. 4 km NE of Sach Pass, Pangi.

Fig. 38. Irregular bulbous flute moulds and load casts in Agglomeratic Slate; ca. 8 km NE of Sach Pass, Pangi.

Fig. 40. Tillite from the Agglomeratic Slate, ENE of Sach Pass. Note the pebbles reaching into the next layer (below the photo objective cover). Probably the pebbles and boulders dropped into the sediment from floating ice.

Fig. 35

Fig. 38

Fig. 39

Fig. 40

Again dark well-bedded limestone and lenticular dolomite alternate with the arenaceous to silty slates in a 6 m zone.

Then 0.3 m of slate are followed by thick-bedded light grey silt- to sandstone. These rocks show bedding oblique to the top of the limestone. The dip is SSW (200°) with 45° in the latter and SW (230°) with 25° in the sandstone (Fig. 37). But this is no true stratigraphic unconformity as the discordant bedding planes are the consequence of the current bedding in the overlying unit. The slates (2) develop from the carbonate rocks (1). The base of unit (3) is rather sharply defined.

The siltstones and sandstones are rather massive, after ca. 30 m they pass into an alternation of silty slates, phyllitic slates, and siltstone with layers of medium-grained quartzitic sandstone. There is graded bedding with sharp bottom planes of the sandstone or silstone beds. The sequence, after ca. 100 m, again contains two layers of black limestone each being 10 cm thick.

Again quartzites, sandstone, siltstones, silty to arenaceous slates, phyllitic rocks follow — all of light grey to green colour (ca. 100 m).

The intercalated limestones show local dolomitization and magnesitization.

There is enough evidence that the described carbonate zones in the Tanols are stratigraphic and not tectonic intercalations. Though no fossils have been found in the carbonate rocks, from lithology I do not doubt that they represent the Lower Carboniferous Syringothyris Limestone *). SW of the Sach Pass this limestone is missing as it is in several parts of Kashmir, e. g. the Gulabgarh section. NE from Sach Pass Tanols are facially intertonguing with the Syringothyris Limestone which shows that Syringothyris Limestone and even younger beds may be replaced by rocks in Tanol facies towards the SW.

Overlying the uppermost Tanols we find 5 m of white to grey thin-bedded quartzite, quartzitic slates, and black bleaching slates. These basal beds are succeeded by black splintery, partly siliceous slates, arenaceous slates, with black fine-grained sandstone layers. The upper 150 m of this 220 m sequence are more arenaceous.

The position in the section — between the Tanols with the Syringothyris Limestone bands and the Agglomeratic Slates — and the lithology of the conspicuous dark formation, suggest correspondence with the Fenestella Shales.

At the branching of the valley at the huts Dunaihi the dark formation grades into a green, grey, and dark thin-bedded (1—4 dm) alternation of slates, partly somewhat sericitic, silty slates, argillaceous sandstone, and quartzite. The thick development of the Agglomeratic Slate seems to commence with these beds. The first thick-bedded, green, grey, and dark quartzites and micaceous quartzitic sandstones come in ca. 200 m above the base.

About 9 km before the pass the series exhibits flyschoid features. There is graded bedding, flute moulds at the sole of sandstone or siltstone layers, and load deformations (Fig. 38 on Pl. 11).

Between the 9 and 8 km road marks there are very thick-bedded, light siltstones and dark grey sandstones with subordinate laminated slate layers. Near km 8 we find a 100—150 m alternation of black slate and black, grey to green, micaceous quartzitic sandstone. Then the rocks again show the green or grey colours.

The first pebble beds occur where the valley bends from SW to the SSW (ca. 7 km before the pass). Pebbles and cobbles (up to dm-size) are sporadically embedded in dark grey, green sandstone, siltstone, or brown to silvery psammite schist.

*) V. J. Gupta kindly informed me that he recently discovered a conodont fauna of lower Middle Devonian age.

Under the microscope the angular to lenticular or rounded components prove to be carbonate rocks, quartz, quartzite, aplite-gneiss, plagioclase, microcline, tourmaline, siltstone, or schist. The matrix has recrystallized and consists of quartz, plagioclase, green-brown biotite, sericite, epidote — clinozoisite, pennine, ore, and tourmaline.

About 5 km before the pass alteration of the series increases, thus leading to phyllitic and quartzitic rocks. Due to the strong schistosity the components of the pebbly beds are elongated (Fig. 39 on Pl. 11). Locally phyllitic crenulation is superimposed on the pebbles at right angles to their length axis.

The beds are rather disturbed. The medium dip towards SSW in the lower formations becomes steep with the Agglomeratic Slate, and turns to SW-WSW (see Pl. 4). From the 5 km mark on the dip varies between ENE and NNE with high angles.

The WSW plunging B-axes in the Crystalline and the basal beds of the synclinorium are replaced by SSE to SE plunging axes in the disturbed area from km 5 to the pass. This indicates that the Sach Pass Syncline, the core of which is formed by the Agglomeratic Slate, will end close shortly to the NW.

The remaining ascent to the pass is in sandstones, white to light green quartzites, psammite schists, partly laminated siltstones and phyllites. These rocks are frequently conglomeratic or contain breccia layers (Fig. 40, 41 on Pl. 11 and 12). The rounded or angular components are in layers or sporadically embedded. They are unsorted and may reach across bedding planes. A good deal of the components is derived from the same formation. The deposits have a distinct tillite character. Probably the pebbles and boulders dropped from floating ice into a sea in which flyschoid conditions of deposition prevailed. The rock material rich in silt, graded bedding, flaser structures, and flame structures, which are caused by synsedimentary gliding, indicate a flysch environment.

The intensity of alteration as well as of tectonic deformation shows great variation.

The steep north-eastern dip N from the pass changes to a medium to gentle south-western dip SW of the pass. In a SSW dipping psammite schist (190/30) elongation of the pebbles is SW (220/22), B of the phyllitic microfolding plunges SE (125/13). Thus the main deformation which probably was related with thrusting shows axes across the regional strike — such as in the underlying Crystalline and the Chail Nappe. The younger phyllitic crenulation has the regional NW-SE strike of the Himalayas.

Descending the SW - slope of the Sach Pass the number of pebbles decreases and the series passes into a formation of laminated grey, green to silvery phyllites or psammitic schists. The rocks are crumpled along the SE axis.

Beyond the stream from the W, which is crossed by the trail, the series passes into medium to dark grey, laminated phyllitic slates. These rocks also contain thin dirty grey silt- or sandstone layers. Graded bedding is common.

PLATE 12

Fig. 41. Tillite from the Agglomeratic Slate of Sach Pass, ENE from the pass. Angular and rounded pebbles in arenaceous to argillaceous beds; the latter are deformed by subaqueous gliding.

Fig. 42. Tillite from the Agglomeratic Slate of the north-eastern limb of the Kalhel Syncline; N of Kalhel, Chamba.

Fig. 44. Schistose tillite from the Agglomeratic Slate of the south-western limb of Kalhel Syncline; near the road bridge across the Gunu river, Chamba.

Fig. 45. Coarse-grained, porphyric metagranite; road outcrop E of Kajair, Dhauladhar Range, Chamba.

Fig.41

Fig.42

Fig.44

Fig.45

Under the microscope the siltstone layers consist of quartz, detritic feldspar — microcline and polysynthetic plagioclase, — sericite, chlorite, very small amounts of green-brown biotite, ore, and zircon. The crumpled phyllitic laminae consist of larger quantities of muscovite-sericite, chlorite, then quartz, tourmaline, ore, and clinozoisite.

These beds resemble the Late Precambrian-Early Palaeozoic slate formations (Dogra Slates, Cambrian of Kashmir etc.). The overlying psammite schist — phyllite formation seems to represent the Tanols. In spite of careful search — and there are continuous outcrops SW of Sach Pass — neither the black Fenestella Shales nor the Syringothyris Limestone have been observed between the Tanols and the Agglomeratic Slate. There is a passage between the two latter formations showing no trace of carbonate rocks or the conspicuous black slates. To explain the different sequences in the two limbs of the Sach Pass Syncline it is suggested, that the Syringothyris Limestone, which is interfingering with Tanols NE of the pass, and the Fenestella Shales are entirely replaced by Tanols towards SW. This means that the upper formational boundary of the Tanols varies in NE-SW direction being near the Devonian — Carboniferous boundary in the NE and is as young as Upper Carboniferous in the SW.

About the south-eastern continuation of the Sach Pass Syncline we have some information from STOLICZKA (1866, p. 340), LYDEKKER (1878, p. 54—55) and MCMAHON (1885, p. 90—92). There is no doubt that the Agglomeratic Slate crosses the Chandra valley at its bend between the villages Saor and Sheli and continues SE for some distance (Pl. 4). On the origin of the conglomerates LYDEKKER was the first who assumed ice as means of transport and who made correlation with the Talchirs of the Indian Subcontinent. This view is generally accepted (GANSSER, 1964; FUCHS & GUPTA, 1971; POWELL & SAXENA, 1971, [not in regard of age]).

From Dr. HUTCHISON's observations it is possible that the Crystalline plunges towards SE and a syncline develops E of Kilar (MCMAHON, 1885, p. 90). He describes the "conglomerates" (Agglomeratic Slate) ca. 6 km SE of Kilar and boulders of these rocks in the valley of the tributary ENE of Kilar. The possibility of this other syncline parallel to the Sach Pass Syncline is indicated in our Pl. 4. The Kilar Crystalline might reappear in the lenticular crystalline mass reported from N of Tandi. Anyhow, the Agglomeratic Slate has large extension in the upper Chandra valley and its framing ranges.

The two limestone bands (ca. 40 m each) at the base of the conglomerates at Sugwas (S of Saor, MCMAHON, 1885, p. 90) apparently are the direct continuation of the Syringothyris Limestone NE of Sach Pass.

From the extension of the Agglomeratic Slate towards SE it may be assumed that the carbonate rocks around the village Tandi represent the Lower Carboniferous Syringothyris Limestone, which forms the youngest formation near the SE end of the Sach Pass Syncline*). These carbonate rocks were assigned to the Kuling series by LYDEKKER (1883, map) and Permo-Carboniferous by GANSSER (1964, Pl. 1 A). My experience from the Sach Pass area is in favour of this view (FUCHS& GUPTA, 1971, Pl. 1, and Pl. 1, 4 of present paper).

To continue the description of the section SW of Sach Pass: Along the trail going down the valley to Alwas outcrops are scarce. We leave the Dogra Slates and get into horizontal or gently dipping Tanols. They consist of green to silvery phyllites and psammite schists. Conglomeratic layers make the boundary arbitrary with the overlying Agglomeratic Slate.

*) Recently it is reported that the Tandi limestones contain Mesozoic beds.

At Alwas the dirty grey slates, siltstones, and sandstones reappear. From here to Trela we find silty slates and phyllites, frequently laminated, siltstones, sandstones and quartzites which show irregular bedding planes disturbed by burrows. The latter rocks weather in irregular blocks. The resemblance to the Dogra Slates and Early Palaeozoic rocks of Kashmir is obvious.

After a gentle SSW dip at Alwas the dip becomes NNE at very low angles, and the above rocks form the lower parts of the slopes on both sides of the valley. Light green, silvery sericite phyllites and schistose quartzites, fallen from higher parts of the slope near Baira, show that the Tanols are still above. S of Baira dikes of medium-grained metadiabase are found in the Dogra Slates along the road. There are also rock types reminiscent of Simla Slates.

The Dogra Slates are rather flat to horizontal, but between milestones 7 and 6 (before Tissa) we get into the Tanols again. I suspect tectonic complications, e. g. a fault or recumbent folding, which I was not able to decide on this rather hurried traverse.

The Tanols form the country rock until S of Tissa. They consist of green to silvery sericite phyllites, schists, and slates often laminated, and rather subordinate quartzites. Near milestone 5 there is an occurrence of metadiabase. The medium-grained blocky rocks show under the microscope: Idiomorphic hornblende and former plagioclase crystals make the ophitic structure. The groundmass consists of epidote-clinozoisite, chlorite, sericite, talc, quartz, acid plagioclase, carbonate, sphene, and ore. The original brownish hornblende is largely replaced by blue-green or colourless hornblende, chlorite, sphene, ore, and talc. The former plagioclase richer in An is replaced by epidote-clinozoisite, sericite, and albite.

S of Tissa the underlying Dogra Slates come up again with a gentle SW dip. They consist of grey to black phyllites with arenaceous or silty layers. S of the tributary river from the E they pass again into the overlying Tanol Formation. The named river brings boulders of Agglomeratic Slate and of Panjal Trap from the snowy range in the E.

The Tanols along the Tissa—Tikri road consist of silvery, green, but also dark grey phyllites, siltstones, schistose quartzites, quartzites, metadiabase, and tuffaceous layers. The argillaceous frequently finely laminated rocks, predominate.

A tuff under the microscope shows quartzite and siltstone graded laminae. All over the slide we find chlorite, epidote-clinozoisite, sericite, and sphene, enriched in certain layers.

Towards the Tikri valley the SSW dip gradually steepens to 60°.

S of this tributary the Tanols — laminated and graded phyllites, siltstones, schistose quartzites — are penetrated by dikes of metadiabase. Tuffaceous layers become frequent.

One thin-section of a tuff shows an aggregate of chlorite, carbonate, quartz, epidote-clinozoisite, sericite, slender crystals of plagioclase, sphene, ore, etc.

The Tanols are overlain by blocky, light green, amygdaloidal trap and tuffs (after the km pole 52 [before Chamba]). These rocks have a thickness of ca. 400 m, and dip SW with 30—40°.

At the top the tuffs grade into typical Agglomeratic Slate: Dark phyllites, partly somewhat calcareous, and sericite-chlorite schists (tuffs), massive silt - and sandstones contain rounded to angular pebbles and cobbles of sandstone, quartzite, quartz, phyllite, and iron ore. There are typical tillites (Fig. 42 on Pl. 12). The correlation with the Agglomeratic Slate of Kashmir has been proved also by fossil evidence (GUPTA, 1971, p. 646). The great similarity of these rocks with the Blaini tillites of the Simla area was already noted by MCMAHON (1881, p. 306).

The rocks steeply dip SW, become vertical, and finally dip NNE.

Towards the southern boundary of the Agglomeratic Slate (Fig. 43, 1) there is a zone rich in sericite-chlorite schists (ca. 50 m, 2) followed by 30 m of black slate and phyllite (3), and ca. 40 m grey and green pebbly phyllites and arenaceous slates (1). After 30 m of black slates and phyllites (3) and ca. 100 m of normal conglomeratic slates and phyllites (1), the series becomes green with 20 to 40 m of schistose trap and schists cut by trap dikes (4).

The thickness of the Agglomeratic Slate from the top of the northern trappean rocks to the last named trap is about 1500 m.

Then come 150 m black, pyritiferous phyllites dipping SSW with 50—60° (5).

From these phyllites develops an alternation of black phyllite and dark limestone (ca. 250—300 m, 6). Near Kalhel the dark phyllites disappear and we find a thick-bedded, dark grey to blue limestone series with a few layers of carbonate quartzite and -sandstone or light grey dolomite (7).

At the fossil locality immediately N Kalhel (McMahon, 1881, p. 306) there are lots of large (up to 1.5 cm) crinoid stems to be found. I joined an excursion of Chamba University at Kalhel and in my presence a student found an ammonoid. The fossil was later described by Gupta & Bedi (1970). The fossiliferous limestones show sericitic s-planes and thus have suffered phyllitic alteration as the surrounding rock series.

Along the road W of Kalhel we find ca. 150 m of light limestones and dolomitic limestones, carbonate quartzites, slate, and blue limestones (8). Then we get into blue limestones and dark, black slates with frequent crinoids (9). The beds are vertical or steeply NNE dipping.

Then come nearly horizontal light grey, white, cream, or blue quartzites, carbonate quartzites, with very subordinate slates (10).

Towards S the dip turns to ENE at an angle of 25° and we come into lower parts of the quartzite succession. Here more carbonate layers come in (11), followed downsection by black, grey, and green slates and sericite phyllites with thin (3—10 cm) blue limestone layers (ca. 130 m, 12). After 60 m of black slate and phyllite (13), we find a 30 m outcrop of much deformed green trap with intercalated black phyllites (14). A thick pile — ca. 800—1000 m of black to grey phyllites, slates, silty slates, with a few layers of brown sandstone and light and black quartzite lie beneath (15).

At the Gunu stream, we come into a 200—300 m zone of normal Agglomeratic Slate (1), consisting of blue, grey, and greenish, dark, silty or sandy boulder slates (Fig. 44 on Pl. 12).

R e v i e w i n g the route S of Sach Pass we had to cross a wide anticline consisting of flat lying Dogra Slates and Tanols. With the SW dipping Tanols of the Tikri valley we come into the Kalhel Syncline. The frequency of tuffs in the top-near Tanols may indicate the begin of the Panjal volcanism. Volcanic rocks are confined to the lower and upper boundaries of the Agglomeratic Slate.

The sequence around Kalhel is inverted, thus the limestones and black phyllites, which are younger, dip beneath the Agglomeratic Slate. The black phyllites (Fig. 43, 5) may represent altered Gondwana beds (Fuchs & Gupta, 1971, p. 94), whereas there is evidence now that bed 6 and possibly part of bed 7 are Zewan Formation (Gupta, 1971). From lithologic analogy I favour a Lower Triassic age of the beds 7 to 9, and 11.

The youngest beds exposed along the road are the quartzites (10), which may represent the more arenaceous horizons of the Kashmir Middle Triassic. The top of the mountain S Kalhel consists of the youngest beds which form the core of the syncline. Seen from afar and from the talus they may be quartzites or dolomites.

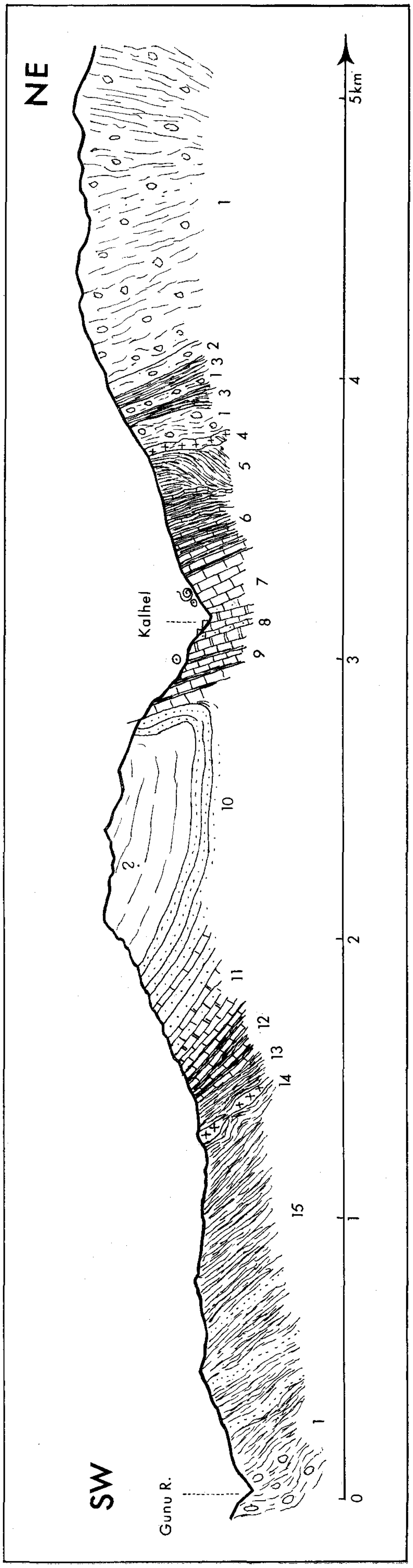


Fig. 43. Section across the Kalhel Syncline. Description in the text.

The SW-limb shows a sequence corresponding to the NE-limb, however, it is somewhat reduced.

It is interesting that the characteristic pebbly slates (1) appear 800—1000 m below the trap in the S whereas in the N they immediately follow the trap. Apparently the dark slates and phyllites (3) increase in importance and replace the pebbly slates towards the S (15).

POWELL & SAXENA (1971) referred to this southern occurrence of boulder slates (Gunu valley) as tillite. They suggested Lower Carboniferous or older age, as the overlying Kalhel Limestone has been assigned Lower Carboniferous by GUPTA & BEDI (1970). In the meantime GUPTA was able to find fossils (1971) which have proved my stratigraphic interpretation (FUCHS & GUPTA, 1971, p. 94). Thus there is no reason now to doubt the correlation with the well-known and near Upper Carboniferous-Permian tillites.

As given above the characteristic conglomeratic slates are only 200—300 m thick. Towards the base the pebbles become scarce and the rocks pass into a monotonous, often laminated series of dark grey to black arenaceous or silty slates and phyllites.

Near Kandela (not in map, 33 km to Chamba) these rocks become steeply dipping (70°). Then between km 33 and 30 intercalations of light quartzites, quartzitic sandstone, and silty sericitic schists similar to Tanol rocks come in. However, they are interbedded with the above dark slates, and typical Tanol Formation is missing.

At the village Koti we come into a new formation reminiscent of Simla Slates or Dogra Slates. Compared to the overlying series they are more resistant to weathering. They are medium grey to green slates and fine-grained sandstones. These rocks are somewhat siliceous. Lamination and graded bedding are common. Growth of sericite, chlorite, and small biotite indicates alteration in greenschist facies.

At the road crossing I took the Chamba road and went through these rocks until 15 miles before Chamba (beyond the village Dugh). There the road comes into the overlying complex of softer slates and phyllites. First there are green, sericitic, silty schists which are overlain by dark, silty to arenaceous slates.

The rest of the road to Chamba we find grey to black, also green slates, siltstones, phyllites, with some layers of light green, grey sandstone and quartzite. The rocks which resemble Simla Slates dip NE at varying angles.

From Chamba I ascended the Dhauladhar Range via Drammane—Kaljair and followed the road to Dalhousie.

SW of Chamba there are thick alluvial conglomerates, the boulders mainly consist of the granite-gneiss of the Dhauladhar Range. The first outcrops of the country rock are much disturbed NNE or SSW dipping light, sericitic quartzites, arkose-quartzites and grey, green, laminated silty slates. This series of arkose-quartzites with conglomeratic layers, sericitic schists, etc. is found until the steep tectonized border against the metagranite is reached. The dip is mainly 50° NE, B plunges E.

I do not doubt that the series in contact with the granite-gneiss represents Chail. In the Dhauladhar Range we find the structural unit which I have described from the Kishtwar Window. The thrust, which separates the Chail Nappe from the overlying Crystalline Nappe, I expect below the terraces SW of Chamba. The Simla Slates — Dogra Slates of Chamba form the base of the Chamba Synclinorium and of the Crystalline Nappe. The thick high grade metamorphic complex of Pangi or Kishtwar is missing in the S. This observation has a parallel in Kashmir.

The granite complex which forms the Dhauladhar Range mainly consists of light, coarse-grained, porphyric, two-mica metagranite to granite-gneiss (Fig. 45 on Pl. 12). The idiomorphic phenocrysts of microcline show Karlsbader twins and reach sizes of 10 cm. However, they are frequently deformed by cataclasis, which is clearly visible throughout the rocks. The gneissic structure is more or less pronounced. Basic nodules have been observed in this granite variety.

There are also medium - and fine-grained portions and dikes in the above variety. These non-porphyric metagranites represent somewhat younger injections in the composite intrusion. Fine-grained dikes contain tourmaline and may show marginal rims of pegmatite.

The granite-gneiss between Chamba and Dalhousie dips NE at an angle of 40—55°.

The southern boundary of the granite-gneiss runs through the town of Dalhousie (near the Tourist Office). Here we get into Chails again, which dip beneath the metagranite. Thus the latter forms an intercalation in the Chails.

The Chails consist of light green to silvery, silky slates to sericitic phyllites with layers of schistose siltstone and quartzite, the latter being subordinate. The rocks are laminated and thus resemble many Tanol occurrences in Kashmir.

In the topmost Chails there are several small bodies of green, grey, hard contact rock. Under the microscope we find large (up to 3 mm) grains and prisms of andalusite, which show excellent sieve structure. They enclose quartz, ore, mica etc. Along fissures and grain boundaries the andalusite is replaced by sericite. Quartz forms a plaster. Biotite is of green-brown colour and contains sagenite; there is muscovite and much sericite, some chlorite, ore, and tourmaline. From the slide it is clear that the original contact rock has undergone alteration in greenschist facies.

Continuing the section SW of Dalhousie we get into a 150—200 m band of cataclastic augen gneiss at the base of the Chails. This orthogneiss is underlain by grey-green, dark, dirty coloured slates, silty slates with sandstone and quartzitic layers. The rocks resemble Simla Slates. In this series there is a 80—100 m zone of blue-grey limestone, which by alternation passes into the surrounding slates. The thin-bedded limestone, which contains numerous slate layers, reminds very much of the Langrial Limestone (Hazara), of the limestones described from the south-western slope of the Pir Panjal (chapter 1.1.1.) and from the Simla area.

The much disturbed limestone dips NE at steep to medium angles. It is underlain by some tens of meters of dark grey to black, bleaching slates. At Naini Khad the road crosses the Main Boundary Thrust and enters the Tertiary Zone.

In the map of McMAHON (1885) the limestone and the slates are assigned as "Carbo-Triassic". The "Volcanic Series" at their base may represent a band of Panjal Trap thrust onto the Tertiaries along the Main Boundary Thrust. The volcanic rocks, however, were not observed in the road section described.

The Dalhousie section corresponds very well with that of the Panjal Range. The Tertiaries are overthrust by a nearly non-

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PLATE 13

Fig. 50. Facetted and striated boulder from Tanakki Boulder Bed, Khotidi Quabar, Hazara.

Fig. 47. Hazara Slates exhibiting graded bedding with flute moulds on sole planes. Lora — Maqusud road near the village Phala, Hazara.

Fig. 48. Hazara Slates showing cross-stratification and load convolutions (upper left). Lora — Maqusud road, Hazara.

Fig. 46. Twisted and granulated flute casts in Hazara Slates. Sherwan road W of Abbottabad, Hazara.

Fig.46

Fig.47

Fig.48

Fig.50

metamorphosed unit, which in turn is overthrust by the epimetamorphic Chail Nappe. The sequence of the Parautochthonous Unit, however, is more reduced here. It consists entirely of the Simla Slates and the interbedded limestones.

There can be no doubt that the granites of the Dhauladhar Range are intrusive in the Chails and form part of the Chail Nappe. In my 1967 paper I have explained them as outliers of the Crystalline Nappe on the few informations from older literature. My studies in the course of the 1969 expedition have revealed the structural picture given in FUCHS & GUPTA (1971, Fig. 1, 2) and in the present paper.

1.3. Hazara (Pakistan) (Pl. 1, 2, 5)

W of Kashmir the regional strike makes a sharp bend and turns from SE-NW to a SW-NE trend. This was named the NW-Himalayan Syntaxis by WADIA (1931). Hazara is situated W of this syntaxial bend.

Easily accessible, Hazara is one of the best-studied areas of the Himalayan region. Exploration started as early as 1866 with the work of VERCHERE. It was followed by WAAGEN & WYNNE (1872), MIDDLEMISS (1896), and recent studies by MARKS & MUHAMMAD ALI (1961, 1962), MUHAMMAD ALI (1962), GARDEZI & GHAZANFAR (1965), and LATIF (1970).

The stratigraphic sequence of Hazara in its older beds is developed in Lower Himalayan facies, from the Jurassic onward it corresponds with the Tibetan Zone. The westernmost part of Hazara in Siluro-Devonian times came into the influence of a carbonate facies which is important W of the Indus (Swabi — Nowshera).

Thus from its geographic position between the Himalayan, and the Afghan depositional areas and that of the Salt Range, Hazara has to be considered in studies on Himalayan stratigraphy. Therefore the author has undertaken a three weeks excursion through Hazara-Swabi-Peshawar and the Salt Range. The author is very much obliged to Dr. M. A. LATIF (Geology Dept., Panjab University, Lahore) for his guidance and the organization of the joint excursion.

In the Salt Range — Hazara region there are several stratigraphic-tectonic zones from S to N:

1. The Salt Range forms an upwarp arch of Palaeozoic to Tertiary rocks along a steep thrust which terminates it in the S. Towards the N its rocks dip beneath the overlying
2. Siwalik Zone a thick development of the Miocene to Pleistocene molasse of the Himalayas. These rocks form the Potwar plateau.
3. The Murree Zone consists of mainly Lower Miocene rocks (Murrees) which have wide distribution in southern Hazara.
4. The Islamabad Zone. This name is suggested for the folded belt of Jurassic to Eocene rocks. In the N the zone is overthrust along a steep disturbance by
5. The Abbottabad Zone. I suggest this name for the unit which exhibits a rich stratigraphic record from the Precambrian to the Eocene. It is characterized by a thick development of the Hazara Slates. The fold belt is nearly non-metamorphosed.
6. The Tanol Zone follows with a thrust at the base; its rocks are altered under the conditions of the greenschist facies. Its stratigraphic sequence comprises the thick Tanols, and the Kakul - and Sirban Formations. The latter two formations were named by LATIF (1970) and replace the former term "Infra Trias". The age of all these formations is in dispute. There are also basic volcanics and granite intrusions in this zone.
7. Farther N high grade metamorphosed rocks lie above. These have not been visited by the author.

The zones of Hazara follow in the form of scales which seem to be rather autochthonous. We do not know how far the thrust at the base of the Tanol Zone continues to the N. In view of the author it probably forms a nappe, which corresponds with the Chail Nappe.

In the following we shall be particularly concerned with the Precambrian-Palaeozoic stratigraphy of zones 5 and 6. I shall go through the formations in stratigraphic order.

1.3.1. The Hazara Slates

The formation, 1000—2000 m thick, consists of green, dirty grey to black shales, slates, silty shales, and green-grey siltstones, subgreywacke-sandstones, and quartzitic sandstones. These rocks frequently occur in cyclic units of several meters thickness. Commonly such a unit commences with current-bedded, quartzitic, micaceous sandstone and passes upwards into grey, medium- to fine-grained sandstone, siltstone, and silty slates.

Lamination, graded bedding, various forms of flute moulds (Fig. 46, 47 von Pl. 13) rill marks, tool marks, ripple-load convolutions, load convolutions, and slump structures suggest deposition in a flysch trough. There are also clay gall breccias, cross-bedding, and ripple marks (Fig. 48 on Pl. 13) occurring together with the above structures. In other deposits they are suggestive of shallow-water origin, in this case they are better interpreted as the product of bottom currents.

There are a few bands of limestone some tens of meters thick. They form stratigraphic intercalations and are partly interbedded with the slate. A light grey, stromatolitic limestone was called Miranjani Limestone by LATIF (1970). The Langrial Limestone is a blue-grey, thin-bedded, nodular limestone interstratified with slate and marl. Also in the calcareous-silty rocks intraformational breccias and current bedding have been observed. Large crystals of pyrite are not rare.

LATIF (1970, p. 10) provisionally has assigned the rank of formations to these limestone intercalations, whereas, the author is inclined to regard them as members of the Hazara Slates.

Occasionally there are chocolate-brown to purple slates (up to 20 m) intercalated in the grey-green coloured formation, e. g. at Abbottabad-Sobrah road. Furthermore, gypsiferous beds are reported by LATIF (1970). LATIF's view that these beds may represent northernmost extensions of the Saline Series facies of the Salt Range is favoured also by the author.

Apart from the above beds which are exceptional, the Hazara Slates are a flysch formation which closely resembles the Attock Slates, Dogra Slates, and Simla Slates. The author regards these as penecontemporaneous. Only somewhat doubtful fossils have been recorded by DAVIES & RIAZ AHMAD (1963) and thus the age remains ambiguous and forms part of the age problem of Lower Himalayan stratigraphy.

In contrast to the thick development of the Hazara Slates in the Abbottabad Zone, the formation is restricted to ca. 200 m in the Tanol Zone, e. g. W of Sobrah (Fig. 49). There the formation seems represented by dark grey-green, partly laminated slates and phyllites which pass into the overlying Tanol Formation.

1.3.2. The Tanol Formation

Characteristic of the Tanol Zone, the formation is missing in the Abbottabad Zone. As the sequence Tanakki Boulder Bed — Sirban Formation overlies both the Tanols and the Hazara Slates, and as Hazara Slates seem to pass upwards into Tanols (e. g. W Sobrah), the stratigraphic position of the Tanols is between Hazara Slate and Tanakki Boulder Bed as also concluded by MUHAMMAD ALI (1962).

The rocks of the Tanol Formation are: Thick-bedded, white, cream, green, grey, pink quartzites and arkose-quartzites with ripple marks and cross-bedding; schistose quartzites, conglomerates and psammite schists. The matrix of the conglomeratic beds may be quartzitic or schistose-argillaceous. The components (up to 8 cm) consist of quartzite, quartz, feldspar, phyllite and graines of haematite-jasper. There are light green, grey, and silvery massive siltstones and laminated silty schists showing graded bedding. Phyllitic slates, phyllites, and chlorite-sericite schists are common. Local black phyllites and quartzites have been observed.

The relative quantities of argillaceous and arenaceous rocks vary widely.

Dikes and sills of metadiabase and greenschist are met in the Tarbela area, along the Sobrah-Khotiala road, etc. These rocks cut the bedding planes of the Tanols but they always show the same schistosity.

Under the microscope they exhibit ghostly ophitic structure. The original minerals are replaced by clinozoisite-epidote, ore, chlorite, and sericite.

There are large intrusions of coarse-grained, porphyric granite in the Tanols, e. g. Mansehra. It is a rather massive biotite-to biotite-muscovite metagranite showing slender tabular phenocrysts of microcline, up to dm sizes. Basic fishes and enclosed blocks or lenses of country rock have been observed.

The whole rock complex has undergone metamorphism in greenschist facies as shown by sericite, chlorite, and the epidote minerals. There is occasional growth of biotite, later partly altered to chlorite.

The lithological identity with the Chail Formation is obvious. In the same way it resembles the stratigraphic position between the Hazara Slates and the sequence Tanakki Tillite — Sirban Formation, which correspond with the Simla Slates and the Blaini-Krol (Shali) sequence respectively.

It is crucial that crinoid bearing carbonate rocks are interbedded with the Tanols between Tarbela and the dam site. These carbonate intercalations were already known to MIDDLEMISS (1896, p. 247, map). However, no fossils have been reported.

The rocks are light to dark grey, cream, pink, and white dolomites and dolomitic limestones. They are generally fine-grained. Cherty and arenaceous layers are frequent and pass into carbonate quartzite, which shows characteristic brown weathering.

Certain layers are rich in crinoid detritus. The carbonate rocks alternate with green and grey schists and phyllites of the Tanol Formation in a dm - to m - rhythm. There are also sills of metadiabase, 2—3 m thick. The main mass of the Tarbela quartzites, dipping ESE at 20—40°, seems to overlie the carbonate zone. The latter is several hundred meters thick.

Though these beds have yielded no fossils except crinoids, the lithology of the carbonate rocks, shows, that they are easternmost parts of the Nowshera - and Swabi Formations. The facial intertonguing of these Siluro-Devonian carbonate formations with the Tanols proves that they are in part of same age. This is also suggested by the observations from Swabi — Nowshera, where Tanols and the named carbonate formations are closely associated.

1.3.3. The Sequence Tanakki Boulder Bed — Sirban Formation

The "Infra Trias" (MIDDLEMISS, 1896) in the last decade has been renamed according to the code of nomenclature and grouped in various ways (MARKS & MUHAMMAD ALI, 1962; GARDEZI & GHAZANFAR, 1965; LATIF, 1970). I disapprove all attempts to group together the Hazira — and Galdanian Formations with the former "Infra Trias".

LATIF (1970) gives the following division of the former "Infra Trias" (from top to bottom):

Kakul Formation:
- Mirpur Member (variegated shales and calcareous sandstones)
- Mahmdagali Member (purple and red sandy dolomites)
- Sangargali Member (red and purple shales, sandstones, and quartzites)
- Tanakki Member (boulder conglomerate)

Thus the Kakul Formation comprises the basal tillite and the varicoloured argillaceous, arenaceous, and carbonate rocks which grade into the blue and grey dolomite complex of the Sirban Formation.

The Tanakki Boulder Bed at the base of the described sequence overlies Hazara Slates or Tanols over a break in sedimentation.

The Pebbles and boulders, up to m-sizes, are of rounded to angular forms partly facetted and show scratches which doubtless are of glacial origin (Fig. 50, 51, 52, 54 on Pl. 13 and 14). The components consist of slate, siltstone, sandstone, or quartzite — rocks which are derived from the underlying Hazara Slates or Tanols. The boulders are densely packed or sporadically embedded in a green, dark grey, or purple shale or silty matrix. The clastic components are badly sorted or unsorted, but the rock is not free of stratification (Fig. 53 on Pl. 14).

Towards the top the boulders become scarce and the unit passes into the overlying red shales, sandstones, and quartzites of the Sangargali Member (LATIF, 1970). The thickness of the Tanakki Member is between 15 and 40 m.

MIDDLEMISS (1896, p. 17—22) finds the conglomerate probably glacial and he considered a correlation with the Talchir Boulder Bed of the Salt Range fairly reasonable. This view is abandoned by modern workers who explain the deposit as a normal basal conglomerate (MARKS & MUHAMMAD ALI, 1961; MUHAMMAD ALI, 1962; DAVIES & RIAZ AHMAD, 1963 a).

Facetted boulders with striations, which can not be explained as tectonic, have been found by the author. They are clear evidence for the glacial nature of the deposit. The boulders, however, can not be derived from afar for they have their source in Hazara. In the Salt Range part of the boulders in the Talchirs is also of local origin — from the underlying Cambrian formations. Considering the geographic position of the Salt Range, its proximity to the north-westernmost outcrops of the Crystallines of the Indian Shield (Kirana Hills) it is not surprising that the boulder content is different from that of the Hazara boulder bed and that the Talchirs include components from the Indian Shield.

The Sangargali Member (LATIF, 1970) develops from the Tanakki Member. It consists of red and purple shales, sandstones, and red and white quartzites. Cross-bedding and ripple marks are not rare. The thickness of that series is up to 60 m.

The above sequence passes into the pink and purple arenaceous and cherty dolomites and limestones of the Mahmdagali Member (LATIF, 1970), e. g. Kakul section.

The road section W of the village Sobrah shows somewhat different relations (Fig. 49). The typical red Sangargali shales and sandstones are succeeded by a 100 m alternation of light grey quartzite, quartzitic sandstone, and green shales interbedded with red, cross-bedded sandstones and quartzites. The green-grey rocks show beautiful ball - and pillow structures, cross-bedding, ripple-load convolutions, and less frequently lamination with graded bedding. These rocks recall Hazara Slates or the Riri Slates of Nepal (FUCHS & FRANK, 1970, p. 15). They represent a somewhat deeper facies, which is intertonguing with the reddish shallow-water facies. These beds are overlain by arenaceous and cherty dolomite of blue-grey colour with a

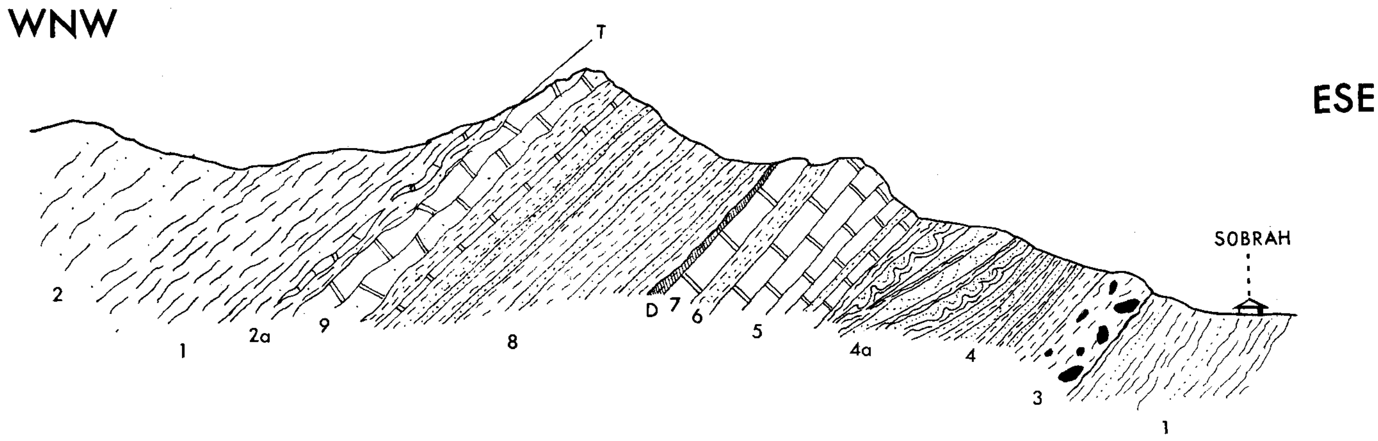


Fig. 49. Section W of Sobrah, Hazara.

1 Hazara Slates
2 Tanol (phyllites, siltstones and quartzites)
2 a Tanol schists with lenses of light grey, cream, or black fine-crystalline carbonate rocks
3 Tanakki Boulder Bed (30—40 m)
4 Red shales, quartzites, and sandstones (Sangargali, ca. 50 m)
4 a Green and grey flyschoid sandstones and shales interbedded with the Sangargalis (ca. 100 m)
5 Blue-grey cherty dolomite with arenaceous layers (80—100 m)
6 Red shales with sandstone layers (15 m)
7 Grey dolomite (15 m); D diabase (6 m)
8 Purple sandstones, quartzites, and shales (ca. 80—120 m)
9 Tectonized grey and pink dolomite and red carbonate sandstone weathering in rusty colours (ca. 30 m).
T thrust
Length of section ca. 2 km.

few white quartzite layers in the deeper part (80—100 m), red shales and sandstones (15 m), grey dolomite (15 m), and again 80—120 m of purple sandstones, quartzites, and shales. At the top of the succession we find grey and pink dolomites and carbonate sandstones followed by overthrust Tanol rocks. The blue-grey dolomites in the above sequence seem to correspond with the Sirban Formation, the rest represent various members of the Kakul Formation. The deviations from the succession found near Abbottabad are due to facies changes, as well as to tectonic complication below the thrust.

Continuing the description of the general stratigraphic development we next come to the Mirpur Member which follows the Mahmdagalis. It consists of red carbonate sandstones and shales passing into the overlying Sirban Formation.

The Sirban Formation consists of light grey to blue-grey, cherty dolomite and dolomitic limestone with sandy and marly layers. Oolites, small stromatolites, intraformational breccias, etc. stress the resemblance to the Krols and especially the Shalis. The formation may attain ca. 700 m thickness.

In the topmost part of the formation there are white quartzites and chert breccias interbedded with the dolomite. These beds, indicating a regression, are also found at the top of the Shalis of the Simla area and of Nepal (West, 1939; Fuchs, 1967, p. 113; Fuchs & Frank, 1970, p. 17—18).

An iron-stained weathering surface indicates a break in deposition at the top of the Sirban Formation.

The sequence described in this chapter is also found in the Tanol Zone. There it is metamorphosed in greenschist facies as are the underlying Tanols (Fig. 55, 56). Shales have become silky slates to sericite phyllites, and the sandstones are altered to very resistant quartzites.

1.3.4. The Galdanian and Hazira Formations

Middlemiss (1896, p. 25—27) described a series of "Volcanic material, haematitic breccia, quartzites, shales, etc." overlying the "Infra Trias dolomite". He emphasizes the existence of an unconformity between the two series and therefore assigned the "Volcanic material etc." to the lower part of his Triassic Series. Gardezi & Ghazanfar (1965) found the series to be independent from the overlying Jurassic limestone and Latif (1970) gave it the name Galdanian.

A varied succession of white quartzites, haematite quartzites, and -sandstones, carbonate quartzites, breccias, and varicoloured shales lies over the weathered surface of the Sirban Dolomite.

The section observed at the village Gehal near Abbottabad shall be given as an example of this conspicuous series (Fig. 57).

In the outcrops shown to the author no volcanic rocks were observable.

From Middlemiss's descriptions (1896, p. 26) it seems probable that siliceous rocks have been mistaken for the "felsitic" material. Thus I doubt the volcanic nature of these rocks following Waagen & Wynne (1872, p. 6 and p. 14).

The rocks of the Galdanian represent deposits of a continental phase after a break in sedimentation. The "felsitic materials" seem to be siliceous rocks — the product of subaereal weathering — as are the haematitic rocks.

Gardezi & Ghazanfar (1965) have shown that the Galdanian may be partly or entirely replaced by a shale formation which they called Hazira.

The base of the Hazira Formation consists of siliceous shales, marls, dolomitic limestones, and dolomites, the main part of shales and siltstones. The section SW of the village Salhad (Fig. 58) is an instructive and typical example of the formation. In the course of a joint excursion with Dr. M. A. Latif (Panjab University) we found the first fossils in the Haziras of that section. The fossils are described in Fuchs & Mostler (1972).

1. The Sirban Formation in its uppermost part consists of light grey to khaki, cherty dolomite and white or light grey quartzite to carbonate quartzite. There are layers of chert breccia.

PLATE 14

Fig. 51. The Tanakki Boulder Bed, NE of Sobrah Gali, Hazara.
Fig. 52. The Tanakki Boulder Bed, W of Mt. Sirban, Khotidi Quabar, Hazara. Note scratches on boulder in upper part of the picture.
Fig. 53. The Tanakki Boulder Bed, W of Mt. Sirban, Khotidi Quabar, Hazara.
Fig. 54 Facetted and striated boulder from Tanakki Boulder Bed; Sangargali, Hazara.


Fig.51


Fig.52

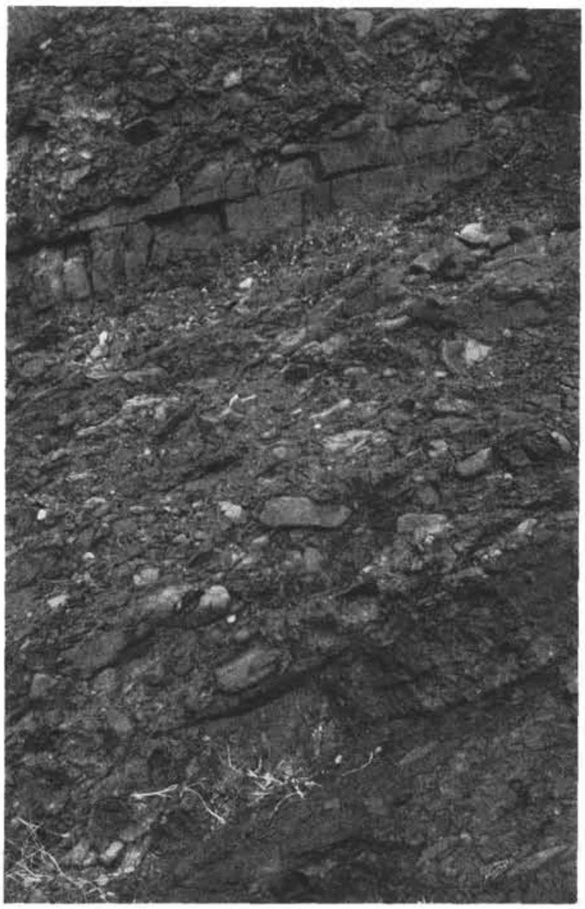


Fig.53


Fig.54

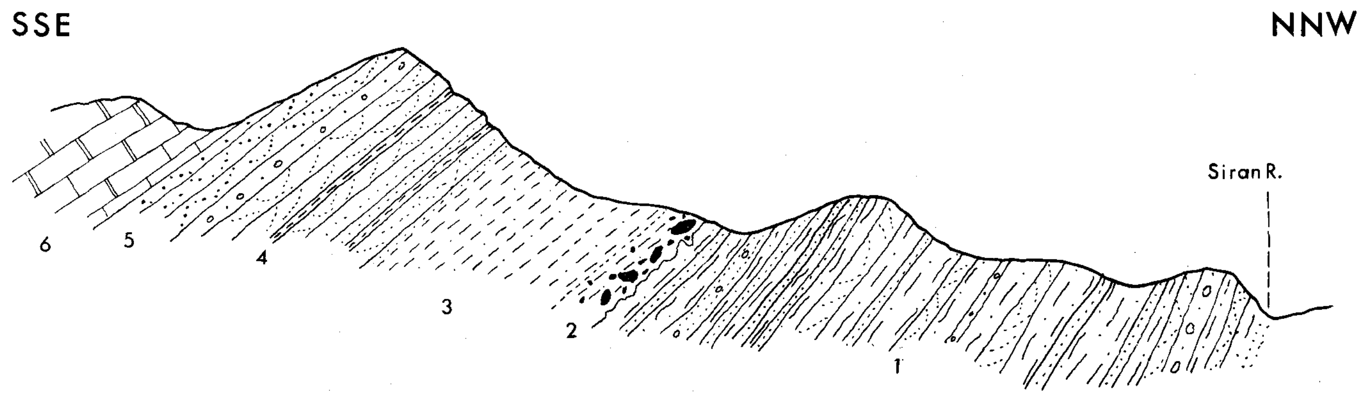


Fig. 55. Section through the northern face of the hill S of Kachhi, the section is about 1 km SW of this village, Hazara.

1 light cross-bedded quartzites, arkose-quartzites, conglomerates, siltstones, slates, and phyllites (Tanol, ca. 500 m exposed)
2 Green to dark grey phyllitic slates containing boulders up to m - sizes. The boulder bed overlies the Tanols on a surface of erosion and reworking (Tanakki Member, ca. 40 m)
3 The boulder bed passes into grey to green phyllitic slates and silty slates, becoming laminated in the upper part. There are a few red layers (150—200 m)
4 Cross-bedded dark red to purple haematite quartzite, grey and green quartzites, and subordinate slates; ripple marks (150 to 200 m). At the top there is a bed of dark fine-conglomeratic quartzite.
5 Coarse-grained, light yellowish quartzite showing cross-stratification (30 m)
6 Grey to blue cherty dolomite and limestone (Sirban Formation)
3 — 5 represent the higher members of the Kakul Formation (LATIF, 1970).
Length of the section ca. 1 km.

2. Dark grey to black dolomite and phosphatic and siliceous oolite showing ferruginous weathering (5 m). The oolites contain siliceous ooids, superficial ooids (up to 1 mm) and coated oolite fragments (up to 2 mm) in siliceous, partly calcareous matrix. The rocks have yielded spiculae of porifera (F 114). They overlie the Sirban Formation on an iron-stained nodular weathering surface.
3. Dark impure dolomites and marly dolomitic limestones (3 m). The spiculae — black, slightly conical needles — are easily visible on the ochre-coloured weathered surface of the rocks (sample F 113).
4. Sandy to silty shales and glauconite sandstones form a 15 m sequence. Some shale layers have bright green colours. The rocks pass into
5. Red to chocolate-coloured shales and silty shales (5 m).
6. Dark grey, soft, silty shales and siltstones weathering in khaki colours (ca. 100 m). Fine lenticular structures, ripple cross-laminations and slump structures indicate a somewhat disturbed environment.
7. The Sikhar Limestone (Jurassic) is a well-bedded blue grey dense or oolitic limestone, containing undeterminable fragments of fossils. The boundary against the underlying rocks is not well-exposed. Tectonic disturbance parallel s is possible and would explain the absence of the Maira Formation. This arenaceous formation elsewhere is found at the base of the Sikhar Limestone.

The fossils obtained in the described section, and which also have been observed in the Haziras near Kakul, indicate a Cambrian age according to MOSTLER (in FUCHS & MOSTLER, 1972).

The age determination of the Hazira Formation gives us the minimum age of the underlying Sirban Dolomite and in consequence determines the age of the much disputed Lower Himalayan sequence. Considering various contradictory observations the author doubts whether the Hazira porifera give an une-

Fig. 56. The Tanakki Boulder Bed (2) overlies the Tanols (1) on a surface of erosion and reworking; SW of Kachhi, Hazara, Drawn after a colour slide.

quivocal age and regards the problem as unsettled (see chapter 2.1.5.).

1.3.5. The Meso — Cenozoic Sequence

There is a rich Jurassic, Cretaceous, and Lower Tertiary development in the Islamabad — and Abbottabad Zones of Hazara. The resemblance of the Mesozoic succession with the Tibetan Zone is very close and I have hinted to probable correlations in a previous note (FUCHS, 1970, p. 22). It is not the aim of the present paper to describe this younger sequence. However, it shall be pointed out that the Jurassics overstep the

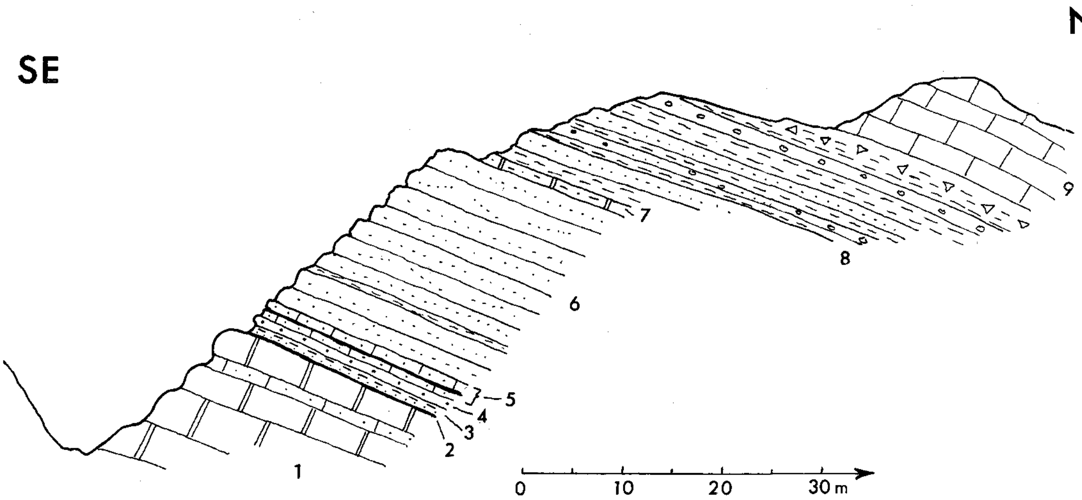


Fig. 57. Section through the Galdanian Formation; at the village Gehal, near Abbottabad, Hazara.

1 Sirban Dolomite (with layers of carbonate quartzite)
2 Red arenaceous shale (0.02 m)
3 Coarse-grained, marly sandstone passing into laminated, grey to khaki, sandy shale (0.6 m)
4 light quartzite (0.4 m)
5 Carbonate quartzite (2 m) containing a 0.1 m layer of red and green shale
6 White and red quartzite with some cross-bedding and ripple marks (ca. 22 m)
7 Red, impure, dolomitic limestone (ca. 1 m)
8 Red and purple shales, sandstones, fine-conglomerates, breccias, haematite etc.
9 Sikhar Limestone (Jurassic) overlies on a sharp boundary
2 — 8 Galdanian Formation.

Sirban Formation and various members of the Kakul Formation down to the Hazara Slates (Middlemiss, 1896; Latif, 1970, and others).

In the more northern unit of the Tanol Zone this younger succession is missing.

R e v i e w : There is left no doubt that the Simla Slate — Krol (Shali) sequence is represented by the Hazara Slate — Sirban succession of Hazara. Arguments in the dispute about their age may be obtained in Hazara, however, they are contradicting. The fossil found in the Hazira Formation indicates a Precambrian to Early Cambrian age, whereas the Tanols intertonguing with the Siluro-Devonian carbonate formations at Tarbela point to an Upper Palaeozoic age of the Tanakki (Blaini) — Sirban (Krol, Shali) succession. It is also crucial that it has been re-established now that the Tanakki Boulder Bed is of glacial origin. The assumption of most Pakistani geologists that the Kakul- Sirban Formations correspond with the Siluro-Devonian Swabi-Nowshera carbonate formations is rather improbable therefore, as no glaciation of that age is known from that part of the world.

The Jurassic — Cretaceous sequence showing Tibetan facies in Hazara indicates that deposition in the various Himalayan regions occurred in neighbouring zones. This fact as well as the existence of Gondwana beds in Kashmir and the eastern Himalayas show that the Himalayan successions were deposited in the immediate neighbourhood of the Indian Shield. Thus the Indian Subcontinent can not have drifted from afar to-

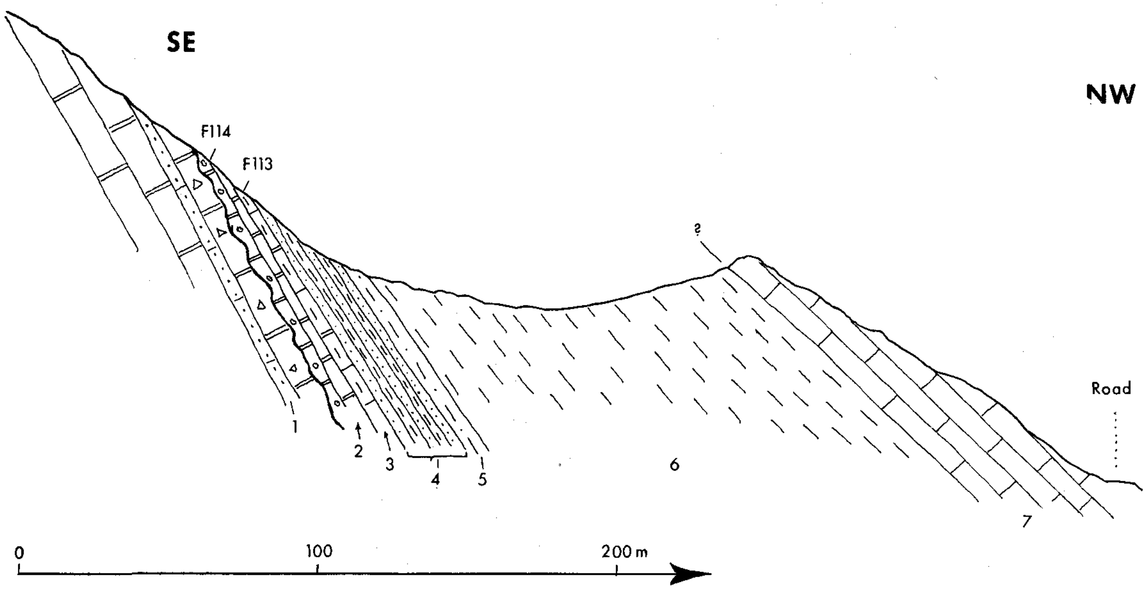


Fig. 58. Section across the Hazira Formation; NW foot of Mt. Sirban, ca. 1 km SW of the village Salhad. Description in the text.

wards the Tethys. This rules out the historical drift hypothesis still held by KANWAR (1972).

As for tectonics we find the rock assemblage of the Chail Nappe in the Tanol Zone. As in W-Nepal the Tanols (Chails) form part of a sedimentary succession corresponding to that of the Parautochthonous Unit (Tansing Unit, Abbottabad Zone). Also the granite intrusions which are a characteristic of the Chails and Tanols in the North-Western Himalayas are represented in Hazara (Mansehra Granite, SHAMS, 1961).

The metamorphism of the Tanol Zone, which is thrust onto the non-metamorphosed Abbottabad Zone, requires a certain amount of tectonic transport. N of Abbottabad the tectonic overlap of the Tanols over various members of the Abbottabad Zone is obvious (Pl. 5). However, we have no information whether the Tanol Zone represents a nappe or whether it is parautochthonous — tectonic windows have not been discovered.

1.4. Swabi — Nowshera (Pl. 1)

The rocks found in western Hazara continue W of the Indus river. At Swabi and in the Nowshera area they are exposed in isolated hills rising from the alluvial plains. The carbonate rocks which have yielded poorly preserved crinoids at Tarbela contain rich faunas in the above named areas (STAUFFER, 1968). Their age is well-established and their relation to Tanols or Hazara Slates shall be described and discussed in this chapter.

1.4.1. Swabi

After early fossil finds by KING (1961) MARTIN et al. (1962) investigated the region between the Lower Swat and Indus rivers. The fossils from the Swabi carbonate rocks are described by DAVIES & RIAZ AHMAD (1963 a) (see also the note DAVIES, 1964, p. 105).

From the descriptions it appears that Tanol rocks have a vast areal extent W of the Indus. The Lower Swat — Buner Schistose Group and parts of the Swabi — Chamla Sedimentary Group seem to represent Tanols. The carbonate series of the above successions have yielded fossils which prove a Palaeozoic age or even allowed determination as Siluro — Devonian. However, there are also series resembling the older Dogra —, Hazara — and Attock Slates. The granites and granite-gneisses (Ambela, Swat) correspond to those of Mansehra, the Pir Panjal, and most probably the Chail granites.

In the region of the reconnaissance survey by MARTIN et al. (1962) thrusts are probably present, as noted by these authors. Thus some of the stratigraphic groups might turn out to be tectonic sequences, which makes interpretation rather doubtful.

We now describe the occurrences visited.

From the ship bridge across the Indus, SW of the Tarbela dam site along the road to Swabi there are several outcrops of typical Tanols: light green and dark phyllites, light, silty slates and schists, chloritic schists, and thick-bedded green, white, and grey quartzites with cross-bedding. According to MARTIN et al. (1962, map) these rocks occur together with carbonate series N of Pihur, which contain crinoids according to STAUFFER (1968, p. 1347). They represent the trans-Indus continuation of the Tarbela carbonate rocks.

N of Swabi, at the village Maneri the hills consist of thick-bedded, fine-crystalline dolomite and limestone, now partly marbles.

These rocks dipping towards E are underlain by Tanols in the spur S of the village Salim Khan. Dark and light green schists alternate with conglomerate-quartzites. Towards the top the Tanol quartzites contain carbonate layers, which weather in rusty colours. This indicates a passage into the overlying carbonate formation (Maneri Marble, ca. 400 m thick) without a break in sedimentation. The latter formation contains crinoids in its basal beds; crinoidal and algal remains are reported by MARTIN, DAVIES & KING (see footnote in DAVIES & RIAZ AHMAD, 1963, p. 1) and gastropoda by MARTIN et al. (1962, p. 8).

S of Swabi the hill between the villages Kala and Panjpir consists of dolomites and limestones. These were called the Kala Limestones and Dolomites by MARTIN et al. (1962), who found the first fossils there. The light grey, pink, or cream coloured carbonate rocks are thick-bedded. They show ferruginous surface when weathered. The rocks are fine-grained to porcelaineous.

The rocks dip W on the E side of the hill, whereas on the W side at the village Darra they are dipping E (Fig. 59). Thus the carbonate series shows a fan like structure and it is uncertain whether they form a syncline or whether the rocks on the W-side are inverted. At the village Darra they consist of dark blue-grey limestones, marls, and shales. These rocks are rich in crinoid ossicles and bryozoa.

On the E side, NE of Panjpir, the rock units underlying the carbonate formation are well exposed (Fig. 59):

1. Dirty green, grey, also light slates, phyllites, and sandstones. The rocks show irregular bedding planes disturbed by burrows, lenticular structures, and laminations. They are reminiscent of Dogra Slates.
2. Ferruginous, arenaceous carbonate rock to carbonate quartzite (1.5 m), unsharp contact with the underlying series.

2. a In the northern section, 2 seems to be represented by a few tens of meters of thick-bedded, fine-grained quartzite. It is green, dirty grey, and white and shows rusty surfaces. Portions consisting of carbonate quartzite weather in patches.

3. Greenish, medium-grained sandstone, crumbling and rusty weathering (ca. 10 m).
4. Black, dark grey, blue limestones, impure limestones, marls, shales, and sandstones alternating (8 m).

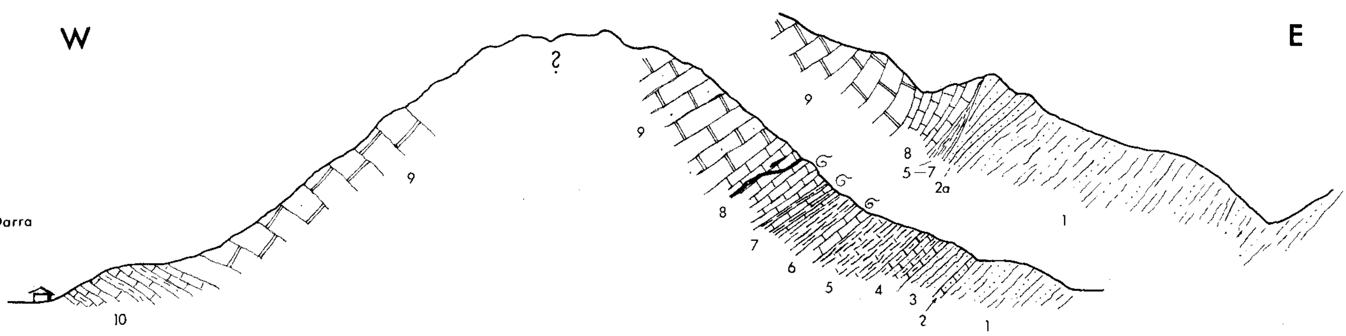


Fig. 59. Sections across the hill S of Kala, Swabi. Description in the text; length of section ca. 1.5 km.

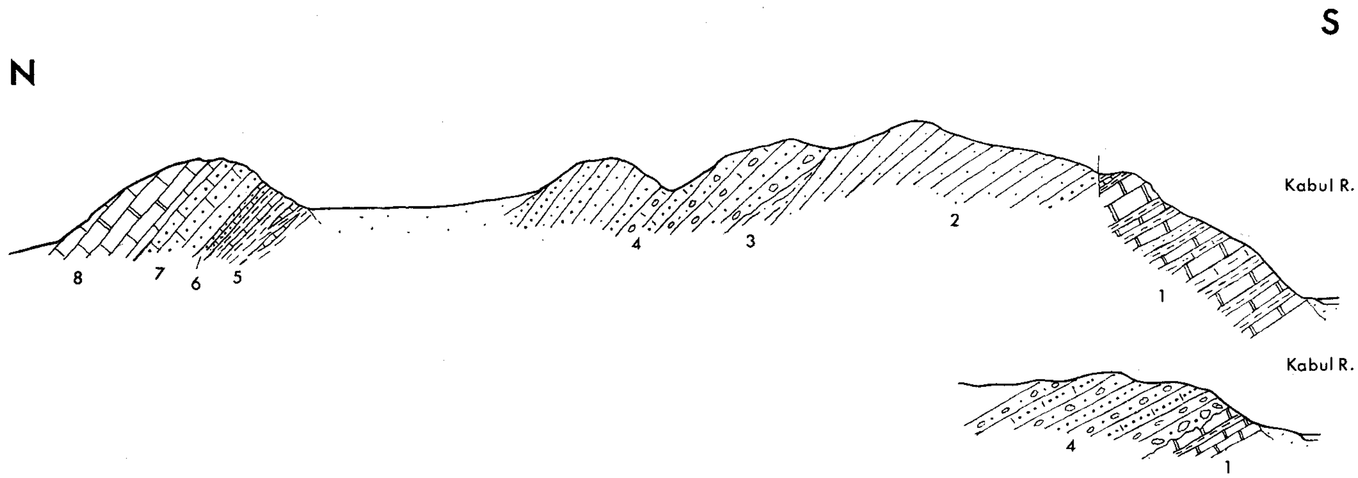


Fig. 60. Sections E of Turlandi length ca. 1.5 km; described in the text.

5. Dark grey, black, partly marly slates (15 m) passing into
6. Crinoid limestone containing much deformed orthoconidae. The rocks are blue-grey at the base and become light coloured towards the top (6 m).
7. Laminated dark shales and slates alternating with dark limestone in the upper portion (15 m).
8. Dark and light grey limestones containing crinoids and orthoconids and layers of schistose crinoid limestone (ca. 25 m). There is a basic sill.
9. Light grey, rusty weathering limestone, dolomites, and very resistant, sandy carbonate rocks (ca. 500 m).
10. Dark limestones, marls, and shales of Darra. In the case that the rocks 9 form the core of a syncline — as it appears — the Darra sequence corresponds to the limestones 6—8 of the eastern limb.

The northern section of Fig. 59 was not studied in detail. The numbers from the southern section are given to probable corresponding members.

It appears probable that 1 represents Dogra (Hazara, Attock) Slates coming up in an anticline. No 2, 2 a, and 3 might indicate the beginning of the Tanol sedimentation. Considering the experience from the Tarbela area it seems probable that the carbonate succession (4—10) replaces part of the Tanols. From the fossils the age of the carbonate complex, however, is Mid-Palaeozoic, most probably Siluro-Devonian (Davies and Riaz Ahmad, 1963 a).

1.4.2. Nowshera Region

Carbonate and quartzite complexes are found outcropping in a series of hills N of the Kabul river. They form the continuation of the formations of the Swabi and Tarbela regions (Tanol Zone), and show the same grade metamorphism. The carbonate rocks of Nowshera have been subject of the detailed studies by Stauffer (1968).

The rocks generally dip N at a medium angle.

The Nowshera reef complex is underlain by the Kandar Phyllites — light greenish-grey, partly silty phyllites with layers of grey marly crinoid limestone. There are a few dikes of dolerite.

The phyllites are overlain with a slight basal unconformity by the Nowshera Formation, consisting of red, pink, white, and light grey limestones and dolomites. They are well-bedded or massive. From the lithology and fossil content, which locally is very rich, Stauffer was able to reconstruct the ecology of this reef complex. The reef was in a warm shallow sea and began to grow in quiet water and slowly grew upward into a rough-water environment.

The carbonate rocks are interbedded with quartzites and are overlain by the thick Misri Banda Quartzite. There is evidence that the carbonates were replaced by clastic sediments towards N and E (Stauffer, 1968, p. 1349) which is consistent with my view that the Siluro-Devonian carbonate formations are replaced by the Tanols towards NE.

The Misri Banda Quartzite develops from the topmost beds of the carbonate complex. It consists of massive, white, pink, and brown orthoquartzite and may reach ca. 500 m thickness.

The Late Silurian — Early Devonian age of the Nowshera Formation is well-established. The Kandar Phyllites which have yielded crinoids only are thought to be very little older (Stauffer, 1968, p. 1333).

The easternmost outcrop between the villages Turlandi and Misri Banda is more complicated and offers certain problems (Fig. 60):

The lowest beds are exposed on the slope down to the Kabul river.

1. Well-bedded, dark to light grey dolomite showing a characteristic greenish weathering colour. The rocks contain small amounts of chert. The stromatolithic structures (Fig. 61 on Pl. 15) most probably are the stromatoporids noted by Stauffer (1968, p. 1342). The dolomite alternates with marl and shale of green, grey, red, purple, and violet colour. The series seems to become varicoloured in eastern direction.
2. In the section studied the overlying Misri Banda Quartzite abuts against the dolomite along a small fault. The basal layers of the quartzite are white to brown, followed by 200—300 m of rather pure, white to slightly yellow, fine-to medium-grained orthoquartzite. Cross-bedding is found throughout the formation. Brown weathering round holes (0.5 cm diameter) locally visible on the rock surfaces seem to have their source in burrows.
3. At the top green silty Tanol phyllites come in.
4. The phyllites and the quartzite are unconformably overlain by the Turlandi Conglomerate, which in the W near the village Turlandi overlies and reworks the dolomites (1). There is a well-bedded sequence of carbonate quartzite several hundred meters thick, which contains many layers of unsorted conglomerate (Fig. 62 on Pl. 15). The carbonate quartzite is grey to blue-grey, very resistant and shows rusty brown weathering colour. Cross-bedding was observed locally. In the conglomerates pebbles and boulders (up to 1 m) of grey dolomite, cherty dolomite, white, grey, and brown quartzite, quartz, and dark slate are embedded in carbonate quartzite matrix. These components are well-rounded, egg-shaped to angular, partly they have been deformed to lenses. The material as well as the shape of the components indicates a local source and little transport. Crinoid stems are found in the matrix as well as in dolomite blocks derived from the underlying series.
The brown weathering rocks are interbedded with white, pure orthoquartzite lithologically resembling the quartzite (2).

A depression filled with alluvial deposits forms a gap in observation. The hill N of it shows

5. Green-grey slates and phyllites containing dm - layers of marl and crinoid limestone. The series resembles the Kandar Phyllites and is exposed in ca. 15 m thickness.
6. Above a top layer of crinoid limestone follow brown weathering carbonate quartzites, 6 m thick. The rocks contain conglomeratic layers. The series passes upwards into
7. Pink, white, and brownish quartzite, carbonate quartzite, and sandy carbonate rock (ca. 25 m) overlain by
8. Flasery, grey, pink, and white carbonates — typical rocks of the Nowshera Formation, however, in the state of marble. Crinoid stems and recrystallized corals are still discernible. The series forms the northern side of the hill and is about 100 m thick.

When discussing the observed section there remains uncertainty whether there is tectonic repetition in the sequence. A thrust or fault might be hidden beneath the alluvial deposits mentioned.

There is no doubt that the sequence of the northern hill (5—8) corresponds with that of the outcrops N of Nowshera. There are several quartzitic intercalations, which have already been recognized by STAUFFER. However, the dolomite series (1) may be an earlier formation not exposed at Nowshera or may belong to the Nowshera carbonate complex representing a lagoonal facies.

The unconformity beneath the Turlandi Conglomerate might support the former possibility. However, at Tarbela rock types of the dolomite series (1) and characteristic carbonate rocks of the Nowshera Formation are both found together intertonguing with the Tanol Formation. Both series have yielded crinoids. Thus I am inclined to follow STAUFFER who assumes that also the lower carbonate rocks belong to the Nowshera Formation. The dolomite series could be somewhat older but not pre-Ordovician.

The slight unconformity at the base of the Nowshera Formation noted by STAUFFER (1968, p. 1333) and our observation of the transgressing Turlandi Conglomerate indicate Caledonian orogenic disturbances. The various and impersistent quartzite intercalations (Misri Banda Quartzite) hint in the same direction. Possibly the orogenic movements produced an environment favourable for reef development.

The significance of the Nowshera reef complex for Himalayan stratigraphy lies in the fact that the well-dated Siluro — Devonian rocks are in stratigraphic contact with the Tanols. This characteristic rock assemblage — including also igneous rocks —, is found throughout the Himalayas (Chails). There it shows the same grade of metamorphism and analogous tectonic position. It also forms part of the Kashmir — Chamba Synclinoria where its Mid-Palaeozoic age is established. In the Lower Himalayas, however, the age of the Tanol — Chails is disputed, as it forms part of the problem of the entire unfossiliferous sequence there. In Hazara we find the typical Lower Himalayan succession together with the easternmost beds of the Nowshera-Swabi carbonate facies. This — in my view — is a strong argument in favour of Palaeozoic age of the Lower Himalayan succession.

In discussing palaeogeography STAUFFER (1968, p. 1349) noted that Siluro — Devonian deposits are missing S from the Nowshera reef complex. Although this is generally true we found an exception in the Attock — Cherat Range S of Nowshera. On an excursion under the kind guidance of Prof. Dr. R. A. KHAN TAHIRKHELI (Geology Dept. of Peshawar University) I was shown the section E of Jabba Khattak (Fig. 63):

1. Attock (Hazara) Slates: Flyschoid slates and siltstones.
2. Langrial Limestone (Khattak Limestone, TAHIRKHELI, 1970) a blue-grey, nodular limestone with shale laminae. Some chert has been observed. The limestone may attain tectonic thickness of 200 m.
3. Brown weathering carbonate quartzite and — sandstone with beds of grey, white, and brown, very resistant quartzite. The series, which is a few tens of meters thick, exhibits cross-bedding. There are basic dikes (D).
4. Tanol phyllites and dark slate forming dm-layers.
5. Green-brown weathering, dark grey, cherty dolomite (6 m). The rock resembles the dolomite (1) of the Turlandi section (Fig. 60).
6. Well-bedded to massive, grey, white, pink marble. The flasery recrystallized carbonates resemble the stronger metamorphosed varieties of the Nowshera reef complex. The thickness of the series may attain a 100 m.

The rock assemblage 3—6 is so characteristic that there is no much doubt left about the correspondence with the Nowshera Formation.

The section goes through the overturned northern limb of a syncline. Thus the carbonate quartzites were at the base of the Nowshera carbonates in that section and originally overlay the Langrial Limestone, which forms part of the slate complex.

The Attock-Cherat Range is the continuation of the Abbottabad Zone of Hazara with its enormous thicknesses of slates (Hazara-, Attock Slates). TAHIRKHELI (1970) subdivided this slate complex into a Lower Palaeozoic and a Jurassic — Cretaceous part — a view with which only few geologists will agree.

The Shahkotbala - and Shakhai Formations most probably represent members of the Kandar Phyllite — Nowshera Formation — Misri Banda Quartzite succession. The fossils mentioned by TAHIRKHELI (1970, p. 10) agree with that interpretation. In this respect it is of interest that on p. 13 a well marked unconformity exists between the Khattak- (Langrial) Limestone and the overlying Shakhai Formation.

Apparently the Siluro-Devonian carbonate facies was not confined to the Tanol Zone but transgressed southward on the Precambrian-Lower Palaeozoic (?) slate complex of the Abbottabad Zone S of Nowshera. As we know of no further occurrences of Siluro-Devonian rocks farther S or in the Salt Range, the outcrops in the north-western Attock-Cherat Range probably indicate the southern margin of the depositional basin. The reef development seems to represent a marginal facies, which is replaced towards N and E by the arenaceous — argillaceous Chail — Tanol facies.

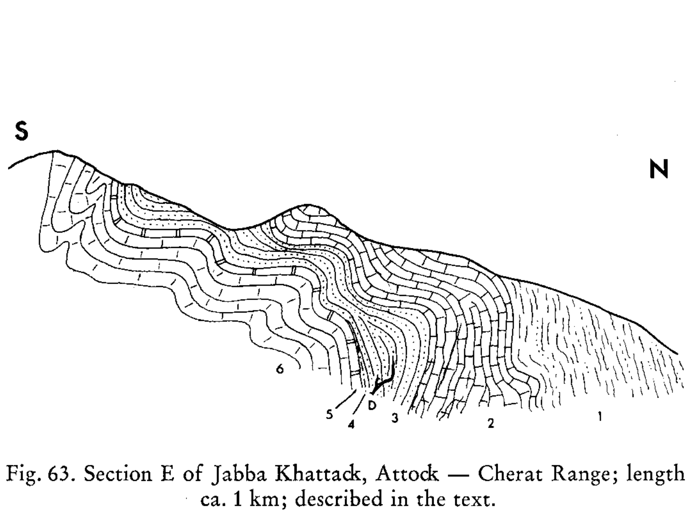


Fig. 63. Section E of Jabba Khattack, Attock — Cherat Range; length ca. 1 km; described in the text.

PLATE 15

Fig.61

Fig.62

Fig. 61. Stromatolites in the dolomite underlying the Misri Banda Quartzite; W of the village Misri Banda.
Fig. 62. The Turlandi Conglomerate, E of the village Turlandi.

2. Conclusions

After the descriptive part we shall now summarize the results, discuss the various problems, and shall try to get a synoptic picture of the geology of the Himalayas.

2.1. Stratigraphy

Huge masses of rocks have been thrust in form of nappes for 100 km horizontal distance in the Himalayas. Thus in all stratigraphic considerations we have to take account of the tectonics. First I give an outline of the stratigraphy in the different structural units and then I shall attempt to correlate across the tectonic boundaries. As our studies concentrated on the Palaeozoic sequences, we omit the Siwalik Zone and briefly refer on the Mesozoic-Cenozoic successions.

We go through the structural units beginning with the lower (southern) ones and passing to the higher (northern) units.

2.1.1. The Parautochthonous Unit

We have to deal here with the stratigraphic developments in the southern parts of the Lower Himalayas, such as the Abbottabad Zone (Hazara), the Autochthonous Fold Belt (Kashmir, WADIA), the Krol Belt, the Tansing Unit (Nepal), etc.

The oldest exposed formations consist of dark, dirty green-grey slates, sandstones, and greywackes, which form thick monotonous successions — the Simla-, Hazara-, Attock Slates. They exhibit distinct features of flysch (compare VALDIYA, 1970) and are geosynclinal. There are subordinate intercalations of purple slates (Hazara), limestones (Langrial, Miranjani, Kakarhatti [2]), Naldera [2]), Limestones etc.), and gypsiferous beds (Hazara, LATIF, 1970) which indicate intertonguing with a neighbouring shallow-water facies.

Doubtful fossils are reported by DAVIES & RIAZ AHMAD (1963 b).

At the top there is transition into a formation consisting of slates, phyllites, psammitic schists, quartzites, tuffs, and basic volcanics — the Chandpurs. The white, green, grey, and purple colours are light compared to the underlying slate formation, and the series is more arenaceous.

The overlying Nagthats comprise orthoquartzites, sandstones, slates, and rare conglomerates of red, white, green, and grey colours. The sedimentary structures indicate deposition in very shallow water.

The thickness of the Chandpurs and Nagthats varies up to 1000 m.

The Nagthats pass into the overlying Blainis, a formation consisting of red, green, white, and grey slates, sandstones, orthoquartzites, magnesian limestones, dolomites, and local jaspilites. The shallow-water series corresponds to the orthoquartzite — carbonate association (PETTIJOHN, 1957). This facies which is extensive in W-Nepal may be replaced by grey, green, laminated and graded slates (Riri Slates) or black slates (Infra Krols) indicating an anaeorobic environment (FUCHS & FRANK, 1970, p. 12—16). These different facies interfinger in various ways.

In the NW-Himalayas in addition we find the tillites (Tanakki -, Blaini Boulder Beds). It should be emphasized that their glacial nature is unquestionable, as shown by facetted and striated boulders. Therefore we refute all attempts recently made to explain these beds as non-glacial (MARKS & MUHAMMAD ALI, 1961; DAVIES & RIAZ AHMAD, 1963 a; VALDIYA, 1970; NIYOGI & BHATTACHARYA, 1971).

In some instances the boulder beds transgress over Hazara - or Simla Slates (e. g. Hazara), and others, e. g. Simla, where VALDIYA (1964, p. 25), and others describe a passage from the Simla Slates into the Blaini Boulder Bed.

Pebbly mudstones, highly suggestive of glacial origin, are found in the Agglomeratic Slate of the south-western part of the Pir Panjal (Kashmir). They are overlain by Panjal Trap, Zewan Beds, and Triassic limestones, thus indicating that the fossiliferous Kashmir facies from the N reached this southern area (WADIA, 1928, p. 248—253; 1934).

From the varicoloured Blaini — or the black Infra Krol facies there are gradations into the succeeding Krol- or Shali Formations. Both formations comprise thick, predominantly dolomitic carbonate sequences, the Shalis rich in stromatolites and intraformational breccias represent a shallower facies. The equivalence in age of Krol and Shali was emphasized by FUCHS (1967) and FUCHS & FRANK (1970). The Sirban Formation and Jammu Dolomites represent Shali facies. The Krol facies is restricted to the Krol Belt and the southern parts of the Mahabharat Range (Nepal). There are recurrences of the black shale facies (Shali Slates). Quartzitic and breccious horizons at the top of the carbonate series indicate regression (Shali Quartzite).

The Jurassic-Cretaceous Tal Formation follows unconformably with flyschoid beds at the base and quartzite-shale successions in the higher portions. The formation has yielded a poor and somewhat endemic fauna and plants, the main portion being devoid in fossils.

In Hazara, the carbonate formations (Sirban) are overlain after a break by fossiliferous beds (Hazira-, Galdanian Formations) their age, however, is in dispute (FUCHS & MOSTLER, 1972).

The above beds are succeeded by a transgressive Jurassic to Eocene marine sequence in Hazara. The development of these formations is equivalent to the Tibetan Zone.

In the Lower Himalayas E of Hazara, the fossiliferous Paleocene-Eocene Subathus followed the Tal Formation. They are overlain by nearly non-fossiliferous Miocene sandstone — shale series — the Dagshais — which are the youngest formation in the succession. Like the Tals the Tertiary formations are also restricted to certain zones of the Lower Himalayas.

2.1.2. The Chail Nappes

The sequences of the Chail Nappes were deposited in the north-eastern parts of the Lower Himalayas and south-western portions of the present day Great Himalayan Range.

The structural unit is characterized by the Chail Formation which is found throughout the length of the Himalayas (Tanols, Berinag Quartzites, series of Kunchha, Dalings, etc.). This individualistic rock assemblage comprises orthoquartzites, arkoses, conglomerates, psammite schists, phyllites, tuffs, and masses of basic volcanic rocks, such as metadiabases, dolerites, amphibolites, etc. From Kumaon to Hazara intrusions of metagranite or granite-gneiss are rather common in the series. The rapid lateral passage from argillaceous or mixed argillaceous-arenaceous complexes into pure quartzite series is characteristic. This underlines the importance of deltas in Chail sedimentation and gives the series a molassic character (FUCHS, 1967), though, there are also flyschoid features (FUCHS & FRANK,

[2]) In my 1967 paper I have given the view that these limestones are tectonically emplaced in the Simla Slates. In the course of my 1969 visit I have found clear sedimentary alternations, which confirmed the views of PILGRIM & WEST (1928), that limestones and slates belong to one series.

1970, p. 34). Apart from the thick carbonate formations of Swabi-Nowshera, carbonate rocks are rather scarce in Tanols and Chails.

In many regions the Chails build up the whole structural unit, but, there are also instances, where they form a stratigraphic succession together with older and younger formations.

Simla Slates are reported from only a few examples. They underlie the Chails and grade upwards into that series (FUCHS & FRANK, 1970, p. 32). The Simla Slates seem to be rather reduced compared to the Parautochthonous Unit.

In Kumaon — Nepal Nagthats, varicoloured Blainis — without the boulder beds — Shali Slates, and Shalis overlie the Chails. This sequence can be closely studied in W-Nepal (FUCHS & FRANK, 1970) where it is not much disturbed. Thus the stratigraphic position of the Chails is clearly above the Simla Slates and below the Nagthat — Shali succession. Thus they occupy the same position as the Chandpurs, which show many lithologic similarities.

The Chails of Chail Nappe 3, which are derived from the northernmost parts of the Chail deposition area, are not overlain by the above sequence but by Lower Gondwanas. FRANK who examined this occurrence was not able to find a sharp separation between the Gondwanas and lithologically similar Chails (see FUCHS & FRANK, 1970, p. 43—44).

The Chail Nappe in Simla, Chamba, and Kishtwar is composed only of the Chail Formation with large intrusions of metagranite (Mandi).

In Hazara the Tanols of the type area are overlain by the Tanakki Boulder Bed on a surface of reworking (Fig. 56).

The varicoloured Sangargalis follow, passing upwards into the carbonate complex of the Sirban Formation.

Thus, as in Nepal we are able to correlate the succession overlying the Chails — Tanols with sequences of the Parautochthonous Unit. Here too, the Tanakki (Blaini) — Sirban (Shali) succession is evidently younger than the Tanols (Chails).

From the Indus to the W the Tanols interfinger with fossiliferous carbonate series (Swabi — Nowshera).

The whole sequence of the Chail Nappe, Tanol Zone, etc. has undergone greenschist metamorphism, except in W-Nepal where the metamorphism dies out in portions of Chail Nappe 1 (FUCHS & FRANK, 1970).

2.1.3. The Crystalline Nappes

We have introduced this term for the next higher structural units, which consist mainly of high grade metamorphic rocks. The composition and the discussion on the age of this complex shall be given in chapters 2.3. and 2.4. However, there are a few instances where fossiliferous series overlie the crystallines: The Devonian Tang Chu series, Bhutan (GANSSER, 1964, p. 205), the Ordovician-Silurian of Phulchauki, Central Nepal (BORDET, 1961, p. 220) and the Ordovician Dhaulagiri Limestone of Jaljala Dhuri, W-Nepal (FUCHS & FRANK, 1970, p. 53—54). In the NW-Himalayas there are fairly complete successions in the synclinoria of Kashmir and Chamba.

All the named occurrences represent series deposited in southernmost parts of the Tethys. It is a problem whether the crystallines had a formerly continuous sedimentary cover or was land area for long periods. The first is proved for the NW-Himalayas (Kashmir — Chamba) where Mesozoic beds from the Tethys have reached even the southern zones of the Himalayas in Hazara (Abbottabad — and Islamabad Zones). For the Central and Eeastern Himalayas I prefer the latter interpretation (FUCHS, 1967).

The sedimentary developments in Kashmir — Chamba are discussed with the successions of the Tibetan Zone.

2.1.4. The Tibetan (Tethys) Zone

N of the Great Himalayan Range there are rather complete, predominantly marine Palaeozoic-Mesozoic sequences in the synclinoria of Spiti, and of northern Kumaon, Nepal, and Bhutan.

Again the succession commences with a thick pile of typical geosynclinal series. These are rather monotonous and commonly they indicate rhythmic sedimentation. In the NW-Himalayas these formations are argillaceous-arenaceous resembling the Greywacke Suite of PETTIJOHN (1957, p. 615—618): Dogra Slates and Cambro-Silurian of Kashmir, Haimantas (Spiti), Martoli (Kumaon). Garbyang Formation and Dhaulagiri Limestone represent a calcareous component in the geosynclinal sequences. In the E the Sangsing La Series (GANSSER, 1964, p. 198) is argillaceous-arenaceous again.

All the named formations grade into the underlying Crystalline — with no basal conglomerates. The lower portions are probably Precambrian. However, the deposits of this type range up into the Cambrian (Spiti), Ordovician and Silurian (Kashmir, Nepal).

In Spiti there is a break at the base of the Ordovician (HAYDEN, 1904).

With the Devonian, facies distribution becomes very complicated, throughout the Tethys Zone, which, according to my view, is caused by Caledonian disturbance.

In Kashmir predominantly arenaceous to psephitic, shallow-water deposits (Muth Quartzite) interfinger with flyschoid argillaceous-arenaceous sequences (Tanol). It appears that the Muth Quartzite with its subordinate carbonate intercalations (Spiti, Kumaon) is replaced by argillaceous series towards SW. This is particularly evident in Chamba where, instead of the Muth Quartzite, we find the argillaceous-siltic, less arenaceous Tanols in Pangi, which are replaced by dark slate-phyllite series in southern Chamba (Pl. 1, 2, 4; Fig. 3, 36, 43). The carbonate rocks which accompany the Muth Quartzite in Kumaon (HEIM & GANSSER, 1939) attain a great thickness in western Dolpo (Nepal) and are replaced by the flyschoid Tilicho Pass Formation in eastern Dolpo and E of that area (FUCHS, 1964, 1967).

Thus in certain regions (southern Chamba and Kashmir, eastern Dolpo) geosynclinal deposition persisted into the Upper Palaeozoic, whereas molasse and shelf sediments formed in nearby areas.

In the Lower Carboniferous the facies differences become less pronounced. Dark argillite-carbonate formations are typical: the Syringothyris Limestone (Kashmir-Pangi), Lipak Series (Spiti), Ice Lake Formation (Nepal) etc. The dark-coloured argillaceous-arenaceous Fenestella Shales (Kashmir-Pangi), Po Series (Spiti) follow the carbonate formations or may replace part of them (see chapter 1.1.5.). Their age is Middle to Upper Carboniferous.

The Carboniferous formations are replaced by the Tanols in the south-western part of Kashmir and Chamba. Thus the Tanol sedimentation continued into the Upper Carboniferous as is also indicated by the passage into the overlying Agglomeratic Slate.

The Upper Carboniferous — Permian Agglomeratic Slate of Kashmir-Chamba is of great interest. Its tuffaceous beds and trap intercalations indicate the beginning of the Panjal volcanism. The latter is related with Hercynian movements, which have brought about a gap comprising Upper Carboniferous and Lower Permian in many areas of the Tibetan Zone (WATERHOUSE, 1966; FUCHS, 1967).

The Agglomeratic Slate is flysch or molasse, including marine horizons as well as plant beds. Its fossil content reveals clear influences from the Gondwana continent, as do the tillites. From HAYDEN's descriptions (1904, p. 51—52) it appears that the glacial beds reached even Spiti. This is important, inasmuch as it shows that not only the southern parts, but also the Tethys Zone of the Himalayas were in the neighbourhood of the Indian Subcontinent in Lower Gondwana times. Certainly the original distance between those regions has been diminished in the course of the Himalayan orogenesis, but there is no room for drift hypotheses in the sense of KANWAR (1972) who assumes drift for thousands of kilometers.

In Kashmir the formation of the Agglomeratic Slate was succeeded by thick lava flows, the Panjal Trap. Lower Gondwana plant beds are intercalated with or overlie the trap. The Upper Permian Zewan Beds indicate a marine transgression commencing another sedimentary cycle, in the course of which the thick Triassic sequence of Kashmir was deposited.

In the western part of Kashmir the volcanic activity persisted until the Middle Triassic (WADIA, 1934).

Upper Permian beds are found throughout the length of the Tibetan Zone (Kuling Series, Productus Shales, Thini Chu Formation, Lachi Series). They are predominantly clastic consisting of sandstones, quartzites, conglomerates and dark shales with local and rather subordinate limestone layers in the higher parts.

As we have not obtained new data on the Mesozoic succession, which does not affect the age problem to be discussed, I point to the outline of the Mesozoic development given by FUCHS (1967, p. 18—22, 198—206; 1968).

2.1.5. The Age of the Lower Himalayan Succession — a Discussion

The geologists working in the Himalayas have to face a fundamental problem — the correlation of the nearly non-fossiliferous sequence of the Lower Himalayas with successions of the surrounding areas. There are two main hypotheses

A. The Chandpur (Chail) — Krol (Shali) succession is Palaeozoic.

B. The Simla Slate — Krol (Shali) succession is Precambrian — to Early Palaeozoic.

There are also workers who envisage a combination of the above hypotheses, such as GANSSER (1964), who accept a Palaeozoic age of the Krol Belt sequence and regard the Shalis as Precambrian. However, it is well-established now that Krols and Shalis are synchronous facies (FUCHS, 1967; FUCHS & FRANK, 1970).

A. This hypothesis resulted from the work of OLDHAM (1888), PILGRIM & WEST (1928), AUDEN (1934, 1948), WADIA (1937), HEIM & GANSSER (1939), WEST (1939), FUCHS (1967), PANDE (1967), PANDE & SAXENA (1968) and FUCHS & FRANK [3] (1970). This view is accepted in the Lexique Stratigraphique (1956), in many hand books on the geology of India, and in part by GANSSER (1964).

Inspite of the differences in fossil content and lithology it is possible to correlate certain members of the Lower Himalayan succession with series of known age.

1. In the Lower Himalayas as in the Tibetan Zone the succession commences with thousands of meters of geosynclinal deposits.

In the Tibetan Zone and Kashmir these monotonous sequences range up into the Lower Palaeozoic (Cambrian — Silurian). From the Lower Himalayas only doubtful fossil finds are recorded (DAVIES & RIAZ AHMAD, 1963 b). From own experience I must emphasize the great resemblance of the Attock-, Hazara- and Simla Slates with the Dogra Slates of Kashmir — Chamba, which seem to be continuous with the Haimantas of Spiti-Lahoul.

2. The Simla (Hazara) Slates pass into the overlying Chandpurs, Chails (Tanols). The character of these rocks, the variability of facies resulting in rapid changes in grain size, the basic volcanic intercalations, etc. establish lithologic identity with the Muth Quartzite — Tanol complex of Kashmir — Chamba. The latter is Mid-Palaeozoic.

This correlation gets additional proof from the Tanols of the Indus region, which interfinger with the Siluro-Devonian carbonate formations of Swabi-Nowshera. It is important to note that the above Tanols in Hazara are overlain by the Tanakki — Sirban Dolomite sequence, which is identical with Blaini — Krol (Shali).

To avoid the apparent inconsistencies resulting from a Palaeozoic age for the Tanols, FRANK (FUCHS & FRANK, 1970, p. 60) assumed the existence of two Chail-Tanol type formations, one Precambrian the other Palaeozoic. However, throughout the entire Himalayas, there is no instance reported where these two formations occur in one section, or where Tanol — Chails stratigraphically lie on Krols or Shalis — they always lie beneath. The close relation of the Palaeozoic Tanols (Tarbela) with the Tanakki — Sirban succession, which overlies the Tanols in Hazara, is convincing evidence against such a view.

3. Of great value for correlation are the boulder beds. The Upper Palaeozoic glaciation of the southern hemisphere has left its traces on the Indian Shield and in the Salt Range. It has also reached Kashmir and even the Tibetan Zone of Spiti with beds highly suggestive of tillites (Figs. 40—42). The age of these beds is proved by marine fossils, Gondwana plants and vertebrates (Kashmir).

There are tillites also in the Lower Himalayas (Blaini, Tanakki), situated between Spiti etc. and the Indian Peninsula and the Salt Range. To assume a Precambrian age for the non-fossiliferous Blainis and Tanakkis means that the Upper Palaeozoic glaciation has left no traces in the Lower Himalayas but has reached adjoining zones in the N. The comparatively complete stratigraphic successions of the latter, however, give no indication of a pre-Upper Palaeozoic glaciation. Thus it appears reasonable to correlate these glacial horizons, though some of them have not yielded fossils.

The "Haimanta Conglomerate" of GRIESBACH (1891, p. 51) referred by AHMAD (1960, p. 646) seems meaningless after HAYDEN's report (1904, p. 9, 11—12, 17—18, 21—22) and the descriptions of the Ralam Conglomerate by HEIM & GANSSER (1939), and GANSSER (1964) who does not consider a glacial origin. Further I have pointed to the probability that the Ralam Conglomerate corresponds to the Ordovician basal conglomerate of Spiti (1967, p. 17, 157, Pl. 4).

AHMAD (1960, p. 647) referred to tillites from the Vindhyans (Late Precambrian) this, however, is not very convincing, particularly if we compare GANSSER (1964, p. 15).

Thus the correlation of the non-fossiliferous Blaini and Tanakki Tillites with the Talchir Boulder Bed and certain horizons of the Agglomeratic Slate has a fair grade of probability.

4. The succession Talchir-Productus Limestone shows lithologic resemblance to the Blaini — Krol or Tanakki — Sirban sequences.

5. The inliers of the Jammu-carbonate series with their abundant stromatolites are identical with the Sirban Dolomite and the Shalis. WADIA (1937) described tuffaceous slates interfingering with the carbonate rocks. An Upper Palaeozoic age of the carbonates is rather probable from the lithologic resemblance of the tuffs with similar beds of the Agglomeratic Slate.

[3] FRANK favours hypothesis B (p. 59—63).

6. There are also some sporadic fossil finds which indicate a Palaeozoic age for the sequence under discussion. Recently GUPTA (1972) found a brachiopod in the Sirdang Quartzite (Kumaon). The quartzite belongs to the Chail Formation and the fossil — *Salopina* sp. — is Palaeozoic, probably Devonian in age. Dr. B. N. RAINA (Geological Surv. India) has kindly informed me, that he has found hystrichospheres of Lower Palaeozoic age in the Ladhiya Formation of Kumaon. This formation corresponds with Chail (FUCHS, 1967, Pl. 4).

MATHUR & EVANS (1964, p. 71—72) record on palaeobotanic fossils which favour Late Palaeozoic age from drill hole samples of a series resembling Krol.

In the Infra Krols of the Naini Tal area (Kumaon) Indian geologists were successful in finding a Lower Gondwana flora (SITHOLEY, SAH & DUBE, 1954; LAKHANPAL, SAH & DUBE, 1958).

7. It seems that the unfossiliferous carbonate formations (Krol, Shali, Baxa, etc.) are replaced by terrestrial Lower Gondwanas in the E and by the Panjal Volcanics in the NW (Pir Panjal Range).

B. The above hypothesis was contested by HOLLAND (1908), MISRA & VALDIYA (1961), VALDIYA (1964), GANSSER (1964), FRANK (in FUCHS & FRANK, 1970) and others. Their arguments concentrated against an Upper Palaeozoic age of the Shalis, HOLLAND and FRANK regard the whole pre-Tal succession as Precambrian to Early Palaeozoic, according to the following arguments:

1. In the neighbourhood of the fossiliferous successions of the Salt Range and the Tibetan Zone it is not reasonable that synchronous formations should be devoid in fossils over such a large area as the Lower Himalayas. The absence of fossils and the abundance of stromatolites in the dolomites may be explained by the assumption of a Late Precambrian age. Thus VALDIYA (1969) on the basis of stromatolites correlated the carbonate rocks of the Lower Himalayas with those of the Vindhyans.

2. The Lower Himalayan sequence shows facies similar to that of Precambrian series of the adjoining Indian Shield, of China, etc. (VALDIYA, 1964). The red quartzites and dolomites, haematite beds, and primary dolomites reflect dry and hot climate, whereas Talchirs and Gondwanas indicate cool and humid climate in Upper Palaeozoic times.

3. The Simla Slates grade upwards into the Blaini Tillite in the Simla area. As most workers agree upon a Precambrian — Early Palaeozoic at the youngest — age, the Blainis can not be correlated with the Late Palaeozoic Talchirs. They correspond with the tillites reported by AHMAD (1960) from the Vindhyans or the Late Precambrian tillites of China (SCHÜLLER & YING SZU-HUAI, 1959).

4. The Mandi metagranites, which intrude the Chails, have given age determinations of 500 ± 100 m. y. on whole rock analyses (JÄGER et al., 1971). This is evidence against the Siluro — Devonian age suggested by FUCHS (1967).

Further KRUMMENACHER's physical age determinations summarized in BORDET et al. (1971) have given Precambrian ages for rock formations corresponding to Chail.

5. The palaeobotanic examinations by Dr. ČORNA (Bratislava, ČSSR), Prof. Dr. W. KLAUS (Vienna University) and Dr. I. DRAXLER (Geologische Bundesanstalt, Vienna) have yielded only primitive globular microfossils in the samples collected by FRANK and me. Such forms are common in several Precambrian formations.

According to MOSTLER (in FUCHS & MOSTLER, 1972) the Porifera remains from the Hazira Formation indicate a Cambrian age. This implies a Precambrian or Early Cambrian age of the underlying Sirban Dolomite.

In my view some of the objections made against hypothesis A have weight, but are not convincing. To briefly discuss these points:

B. 1. The absence of fossils may be explained by assuming that the Lower Himalayan Basin was rather isolated. This is consistent with the extreme scarcity of fossils in the Tal Formation of undoubted Late Mesozoic age, which exhibits a lithology entirely different from synchronous beds in the Tibetan Zone and the Salt Range. Also the thick Tertiary formations, such as the Dagshais, Kasaulis, and Murrees are devoid in fossils. No one would suppose them to be Precambrian. So why should the others be Precambrian.

The Lower Himalayan rocks reflect a facies typically unfavourable for life and the preservation of fossils: Monotonous flyschoid greywacke — slate formations, red quartzite sequences, black shales and algal primary dolomites which are commonly non-fossiliferous (compare CHILINGAR et al., 1967, p. 267—268).

Though stromatolites are common in the Late Precambrian — Early Palaeozoic, they are facies fossils not restricted in age. For instance, HASHIMI (1971, p. 284) reported branching stromatolites from Permian beds in the Kashmir Synclinorium.

B. 2. There are several formations in the Precambrian of the Indian Shield or China which lithologically resemble Nagthat or Blaini and contain stromatolitic dolomites. However, we do not find a succession analogous to the Simla Slate — Krol (Shali) sequence. In particular the basal flysch-greywacke formation (Simla Slates) is missing from the Indian Precambrian. Therefore attempts made to correlate to Precambrian series are rather difficult to sustain whether the correlation is done on the basis of stromatolites, glacial horizons, or lithologic resemblances (VALDIYA, 1964, 1969; FRANK's suggestions are personal communication). No correlation which is consistent with both the geology of the Precambrian and the Himalayas has been found.

As for climate the Blaini tillites are closely related with red beds such as pink dolomites which suggest a hot climate. Locally the matrix of the tillite may even be purple. But the same is visible in the Upper Palaeozoic succession of the Salt Range too (compare PASCOE, 1959, p. 746—754). Such cases may be explained by assuming fluctuations and changes in climate. As in the Pleistocene Upper Palaeozoic glacial and interglacial stadia are to be expected.

B. 3. The dark slates of the Infra Krol or the flyschoid Riri Slates are interbedded with the Blainis or replace them. If there are thousands of meters of Chandpurs, Chails, and Nagthats between these beds and the Simla Slates, as in Nepal, no one would suppose them to be the continuation of the Simla Slates. If they immediately come to lie on Simla Slates, distinction must be difficult.

On the other hand there are instances in the southern parts of the Kashmir - and Chamba Synclinoria where the Simla (Dogra) Slates pass into a thick somber coloured slate formation which replaces the Tanols. Pebbly mudstone intercalations in the upper portions of the thick pile of slates, siltstones, and minor sandstones indicate that we are within the Agglomeratic Slate. The latter is proved by fossils. Thus without a sharp boundary discernible, the basal Precambrian — Early Palaeozoic slate complex appears to grade upwards into the tillite series.

The observations from Simla which are raised as objection 3. may, therefore, be explained in two ways without assuming a Precambrian age of the tillites. Thus the argument is not convincing.

B. 4. Certainly the Mandi granites are proof that the surrounding Chails are at least Ordovician. However, my former view had to be revised also concerning the upper boundary of Chail. The youngest portions of the Tanol-Chails are Upper Palaeozoic in Kashmir-Chamba. Thus my present view is that the formation commenced after the first Caledonian disturbances as indicated by the change from Simla Slate to Chail-Tanol sedimentation. The granites intruded the formation at a relatively early stage — and the sedimentation continued as either flysch or molasse in type. Thus the Chail-Tanols should range from Early Palaeozoic to Upper Palaeozoic.

In regard to the age determinations by KRUMMENACHER we point to the possibility, that detrital micas have been selected for determination. However, it is surprising that these micas, derived from a Precambrian area, should not have been rejuvenated by the Alpine metamorphism of the Chails.

B. 5. The primitive microfossils mentioned may have come into Upper Palaeozoic formations by reworking. In the Blaini tillites, for instance, there is much material of all sizes reworked from the underlying Simla Slates.

On the other hand the stratigraphic value of these forms seems somewhat doubtful.

MOSTLER's view that the Hazira Formation was Cambrian is a serious argument. But also in this case there are contradictory observations. The named formation transgresses on the Tanakki — Sirban sequence ("Infra Trias"), which in turn succeeds the Tanols after a gap. The Tanols, however, interfinger with the Siluro — Devonian carbonate rocks of Swabi — Nowshera.

Evaluating all the arguments discussed, we think that hypothesis A is the more probable. It is easier in Palaeozoic formations to explain the occurrence of primitive fossils which suggest a Precambrian — Early Palaeozoic age, than the reverse. It should be difficult to give reasons for the occurrence of *Salopina* sp. in the Chails or of the Gondwana flora in the Infra Krols of Naini Tal, if these formations are regarded Precambrian.

The intricate problem, however, by no means is settled and further work is needed.

2.2. Facies (Pl. 2)

In view of the questions not yet solved (see above) a summary of stratigraphic development and facies distribution seems of limited value. My views have been presented in several papers (1967, 1968, FRANK & FUCHS, 1970, FUCHS & FRANK, 1970).

An outstanding result from recent studies concerns the Mid-Palaeozoic of Kashmir — Chamba — Spiti. The passage from the Muth Quartzite into the Tanols and from Tanols into a monotonous slate formation towards SW indicates deepening of the basin in that direction. This basin configuration persists into the Upper Carboniferous — Permian as shown by the replacement of the Syringothyris Limestone and Fenestella Shales by Tanols and is indicated by the flyschoid features of the Agglomeratic Slate.

Is this proof against my view of a ridge separating the Lower Himalayas from the Tethys?

Certainly the Palaeozoic-Mesozoic Tethyan facies was never deposited in the Lower Himalayas. Either the latter area was land-locked and a Precambrian sequence after a long time interval was transgressed by the Tals, which show little resemblance to the formations of same age in the Tethys; or the disputed Lower Himalayan succession is Palaeozoic and an arch must account for the absence of fossils and the totally different facies. In either case the Tethys basin did not extend far to the S and SSW.

The above holds good for the Eastern and Central Himalayas but not for the north-western part of the range.

The Kashmir - and Chamba Synclinoria with their Palaeo — Mesozoic successions overlying the Crystalline are an unusual feature of the NW-Himalayas. In Kashmir the Agglomeratic Slate and Panjal Trap even reached the Autochthonous Fold Belt (WADIA). I hold the view that the sporadic occurrences of fossiliferous Palaeozoic beds in the Nepal and Bhutan Lower Himalayas are local, and do not represent relics of a continuous sedimentary Palaeozoic succession, which covered the Crystalline before erosion.

Further, in Hazara the Mesozoic sequence exhibits Tethys facies; thus we must assume a direct communication between the Tethys and the Hazara Lower Himalayas.

In the NW-Himalayas we may therefore expect a more complicated facies pattern.

Though data are incomplete, there are clear indications that the facies belts stretch WNW-ESE across the area of the NW-Himalayan Syntaxis (Fig. 64). The structural lines of the Himalayan orogen have cut these facies belts at an angle. This is particularly obvious in the southern zones least affected by horizontal displacement.

The Krol facies disappears not far W of Simla. The Shali facies reaches the frontal portions of the Parautochthonous Unit at Bilaspur and seems to disappear NW of Mandi. The continuation of the Shali facies belt apparently lies beneath the Tertiary Zone as indicated by the Riasi (Jammu) inliers. It is again exposed in the Abbottabad Zone of Hazara and reaches the Tanol Zone.

In the Pir Panjal elements of the Kashmir Synclinorium, such as the Panjal Volcanic Series, build up a good portion of the Parautochthonous Unit. The fossiliferous carbonate rocks of Uri, Mandi, etc. described by WADIA (1928, 1934) form another example.

The depositional area of the Chail Nappe was NE from that of the Parautochthonous Unit and SW of the Kashmir — Chamba Synclinoria. Formations younger than Chail (Tanol) are missing, with the exception of the "Infra Trias" of the Tanol Zone (Hazara).

From the direction of facies belts and the composition of the Chail Nappe (the coarse clastic rocks of Kishtwar and the Hazara Tanols) we may assume that the Himalayan Ridge of the Central Himalayas probably continued in or near the Chail — Tanol zone. It was a submerged high during Chail times and emergent afterwards. N of it there was a basin with continuous sedimentation, where the sequences of the Kashmir — Chamba Synclinoria were deposited. The Tibetan Zone N of that basin was shallow again, at least in the Devonian (Muth Quartzite).

Also in these northern regions there are indications that facies boundaries stretched WNW-ESE in contrast to the present NW-SE strike. The Muth Quartzite in Spiti and N-Lahoul is missing in Chamba — Pangi, but well-represented in NE-, N-, and NW-Kashmir.

The south-western margins of the Kashmir-Chamba basin are unknown — I think that they formed the frontal portions of the Crystalline Nappe and are eroded now.

There are still too many unmapped areas in the NW-Himalayas to give a conclusive picture. The above trends and rough facies relations, however, are discernible from present knowledge.

Finally we should like to emphasize that throughout the geologic history, the various facies zones of the Himalayas were adjoining the Indian Subcontinent. In the NW-Himalayas this fact is particularly clear, as Upper Palaeozoic glacial beds have reached not only the Lower Himalayas, but also Kashmir, Chamba, and the Tibetan Zone of Spiti. The Gondwana floras and faunas of Kashmir are additional evidence for the proximity of these northerly Himalayan facies zones to the Indian

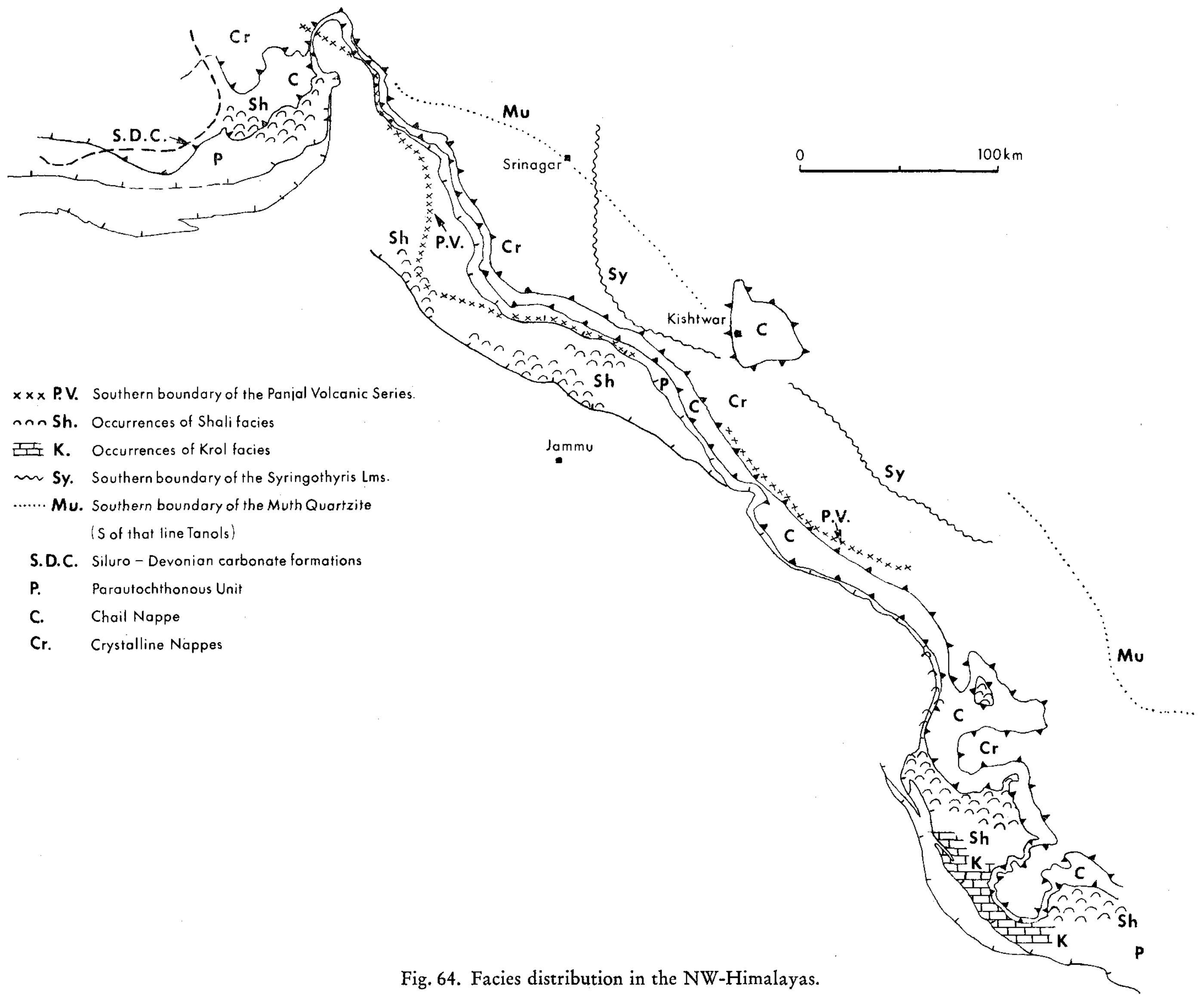


Fig. 64. Facies distribution in the NW-Himalayas.

Peninsula. On the other hand typical Mesozoic sequences of the Tethys transgress the Lower Himalayan succession in Hazara.

Thus there is interrelationship between the Himalayan facies belts, the Salt Range, and the Indian Subcontinent. This must be kept in mind in discussions on possible drift of the Indian Subcontinent.

The maximum displacements in the course of the Himalayan orogeny occurred between the Parautochthonous Unit of the Lower Himalayas and the Crystalline Nappe — thus between the facies belts mentioned above. The folds and imbrications observed in the Tibetan Zone give a relatively small amount of shortening. Along the Indus Suture Line and in the Indus Flysch we again may assume a large amount of shortening. But this zone seems to become less important towards E in the Tibetan Plateau.

The total amount of crustal shortening during the Himalayan orogeny is estimated ca. 500 km by GANSSER (1966, p. 842). This seems realistic and certainly it is not an understatement.

Thus, if we consider drift of the Indian Subcontinent over a distance of several thousand kilometers, we must ask between which zones of the Himalayas this enormous distance has been lost?

In my view there is no possibility to assume such a huge distance between any of the Himalayan zones. Thus all the zones found between the Karakorum — Transhimalaya and the Indian Peninsula were always adjoining to each other. The crustal shortening within this mountain system should be of the order estimated by GANSSER (1966).

2.3. The Metamorphic Complex

It has been the generally adopted view that the metamorphic complex of the Himalayan axial zone was Precambrian (e. g. PASCOE, 1950; GANSSER, 1964, p. 235). However, recently there is much dispute on the age of the alteration.

From the gradational contact between metamorphics and overlying Early Palaeozoic formations and from the sedimentary development FUCHS (1967, p. 151) demonstrated the existence of Caledonian metamorphism. Like GANSSER (1964, p. 252—253) we also were aware of the Alpine metamorphism, thus considering the Crystalline to be polymetamorphic. Recent investigations by KRUMMENACHER and LE FORT (in BORDET et al., 1971), and FRANK (1973) revealed the great importance of the Alpine alterations. FRANK even came to the result that "there are no signs of older metamorphism in the Precambrian to Late Palaeozoic series" (in FUCHS & FRANK, 1970, p. 62).

The existence of Caledonian granites in the Chails revealed by physical age determinations (JÄGER et al., 1971) and the probability that such granites also occur in the high grade metamorphic complex (FRANK, 1973) show that the above view was too extreme. There are several arguments against the view that the Caledonian granites have intruded a non — or slightly metamorphic series:

1. Though K/Ar mineral age determinations are sensitive to later alterations some samples from the Crystalline have given values between 693 and 381 m. y. (KA 341, KA 339, KA 120, BORDET et al., 1971, p. 191—202). Thus there are pre-Alpine mineral ages in the Crystalline.

2. Gneiss pebbles in the Chails (FUCHS & FRANK, 1970, p. 33) and the feldspar content of the Chail arkoses hint to a pre-existing crystalline region. Crystalline components in the Agglomeratic Slate indicate the same thing.

3. The existence of Caledonian granites in the Crystalline is highly probable (FRANK, 1973). The granitic bodies in the high grade metamorphic complex, however, are of a syn-metamorphic type. They are nebulitic-migmatic and pass into the surrounding gneiss complex. Rb/Sr age determinations on whole rock samples of these syn-metamorphic granites shall reveal the age of possible pre-Alpine metamorphism. If these granite-gneisses give a Caledonian age, as I expect, then the Crystalline is polymetamorphic. An Alpine age would show that the whole migmatization and the emplacement of the granitoids was Alpine. However, this result would not imply that the rock complex in pre-Alpine times was virtually unmetamorphosed.

Recent investigations (BORDET et al., 1971; FRANK, 1972) show that the Alpine metamorphism is more significant in the Crystalline than originally assumed by me. Indications of disequilibrium are rather scarce in the mineral assemblages of the metamorphic complex. Nonetheless it seems possible to discern an earlier and a later portion in the Crystalline.

The irregular, nebulitic augen gneiss forms a unit with the coarse-grained garnet-kyanite flaser gneisses, which are rich in pegmatoid layers and lenticles.

The above rocks are intercalated with fine - to medium - grained rather homogeneous granitoid to migmatitic gneisses.

The two rock assemblages are found in Nepal as in the Crystallines of Kashmir and Pangi. In all the named regions the second assemblage proved to be younger. We do not know how much time has elapsed between the formation of these two genetic units, but it seems very likely that they are related to different orogenies.

The lack of relict minerals may be explained that both alterations reached the grade of the amphibolite facies — the latter is the most common transformation in regional metamorphism. The younger alteration was able to reach higher up in the overlying successions, as a thick pile of sedimentary cover had accumulated in the meantime. The mineral assemblages in the earlier metamorphic rocks remained stable or metastable. Locally, however, the rocks have become subject to anatectic mobilization and homogenization — which have produced the fine-grained migmatite gneiss.

At the moment, we can only point to the possibility envisaged above. It is intended to get Rb/Sr age determinations on whole rock samples of the above named gneisses, which shall elucidate the genesis of the metamorphic complex.

2.4. Tectonics

We had to consider the tectonics already in the preceding discussions as tectonics intimately affect stratigraphy and facies. An outline of tectonics and some particular structural discussions shall be presented in this chapter.

The main structural units of the NW-Himalayas are the same as in the central and eastern portions of that mountain range:

1. The Tertiary Zone
2. The Parautochthonous Unit
3. The Chail Nappe
4. The Crystalline Nappes
5. The Tibetan Zone
6. The Indus Flysch

1. The Tertiary Zone consists of two subsidiary units: The Siwalik Zone composed by the thick pile of Upper Miocene to Pleistocene molasse deposits (Siwaliks) shows folds and a few imbrications. It becomes particularly wide in the Potwar plateau.

The Murree Zone overrides the Siwaliks along a steep thrust — the Main Boundary Thrust. The zone is composed by a succession which comprises Shali, Subathu (Paleocene — Eocene) and a thick development of the Lower Miocene Murrees. The sequence is intensively folded. The Murree Zone represents a structural element which is missing in the central and eastern parts of the Himalayas.

2. The Parautochthonous Unit is thrust onto the Tertiary Zone. In the Simla area the composition resembles that of Nepal: Simla Slate — Jaunsar — Blaini — Krol (Shali) — Subathu — Dagshai (Lower Miocene). N of Bilaspur the unit becomes much reduced. The Shali carbonate rocks are exposed in the Aut Window (Kulu valley) and in sheared blocks embedded in the salt bearing Lokhan Formation (see FUCHS, 1967, p. 127—128), N of Mandi. Farther NW the Krols and Shalis appear to be missing, and the unit is mainly represented by Simla Slates. In the Pir Panjal Range the Agglomeratic Slate, Panjal Trap, a few occurrences of Permian — Mesozoic carbonates and Eocene come in. W of the syntaxis, in Hazara, the Shali facies is found again. There even Mesozoic series in Tibetan facies and Lower Tertiaries form part of the Parautochthonous Unit. W of the Indus in the Attock — Cherat Range the unit comprises Attock Slates, the Siluro — Devonian Nowshera Formation (see chapter 1.4.2.), Upper Mesozoic and Tertiary beds.

Whereas the Parautochthonous Unit is well-developed in the Simla area and shows a higher subsidiary unit (Simla Slate thrust sheet), it is confined to a narrow belt along the southwestern foot of the Dhauladhar - and Pir Panjal Ranges. There the internal structure of the unit seems more of a wedge type or consists of a normal NE dipping succession instead of the folds shown by WADIA (1928, 1934).

In Hazara the unit consists of two subsidiary units, which needs special reference.

The Islamabad Zone shows a succession of Middle to Upper Mesozoic to Eocene formations in SE vergent folds. Some of the Eocene occurrences in the basal part of the "Autochthonous Fold Belt" reported by WADIA from the Pir Panjal are probably the eastern continuation of the Islamabad Zone.

The Abbottabad Zone overrides the Islamabad Zone on a steep thrust plane. The zone shows open folds and a few imbrications. Its rocks comprise the Hazara Slates, the Tanakki — Sirban sequence, Hazira and Galdanian Formations, and a rich Jurassic to Eocene development.

3. The Chail Nappe is a continuous structural element, which may be traced through the entire length of the Himalayas. Every geologist who has worked there knows the characteristic epimetamorphic argillaceous and arenaceous successions with the green metavolcanic intercalations (Chails). This series overrides the various formations of the Parautochthonous Unit and is overlain by the crystalline complex. Whereas the Chail Nappe is divided into 3 or 2 subsidiary units and consists of a complete Simla Slate — Shali succession in Nepal it seems to be rather uniform in the NW-Himalayas. It is built up by rocks of the Chail (Tanol) Formation and intrusions of metagranite. W of the Kulu valley the Chail Nappe like the under-

lying unit is restricted to the Dhauladhar Range and the SW slope of the Pir Panjal Range. This is due to the vast extention of the Crystalline Nappe in Chamba and Kashmir. However, there is evidence that the Chail Nappe underlies the Kashmir- and Chamba Synclinoria and the high grade crystallines for at least 60 km in a NE direction. Our discovery of the Chails exposed in the Kishtwar Window supports the ideas of WADIA, who considered the Kashmir Synclinorium to be a nappe.

The existence of the Chail Nappe forming a narrow belt in the SW slope of the Pir Panjal is well-established from our Riasi-Gulabgarh section. The Chails were overlooked in the course of my traverse by car along the Banihal road (FUCHS, 1967, p. 129), but have been found there by FRANK (personal communication) in the course of our 1969 expedition.

W of the syntaxis the unit is extensive in the Tanol Zone. The Tanol (Chail) Formation is overlain by the Tanakki — Sirban succession, which is preserved in several synclines. The Tanol Zone is thrust onto the Abbottabad Zone, but, as no windows hitherto have been found, we have no indication about the distance of movement.

In the Indus region and W of it the Tanol Formation outcrops over a rather large area and is associated with the Siluro — Devonian Swabi - and Nowshera Formations. The northern extention and the boundary against the high grade metamorphic complex is not quite clear from the descriptions by MARTIN et al. (1962).

4. The Crystalline Nappes in the NW-Himalayas consist of a high grade metamorphic complex (amphibolite facies) overlain by the thick Palaeo-Mesozoic successions of the Kashmir- and Chamba Synclinoria. The metamorphism gradually dies away in the named successions; thus Crystalline and sedimentary complex form one structural unit — the Upper Crystalline Nappe.

The Lower Crystalline Nappe is rather thin compared to the upper unit. Its rocks show lower grade of metamorphism (amphibolite to greenschist facies) — migmatites and larger orthogneiss complexes are missing. Its rock assemblage found at Atholi in the Chandra valley as in Nepal (FUCHS, 1967; FUCHS & FRANK, 1970) is identical with the Jutogh Formation of Simla. The unit seems to represent a basal scale of the Upper Crystalline Nappe.

The Zanskar Range, from the Nun Kun in the NW to Lahoul in the SE, forms a huge uplift of the Crystalline (Pl. 1). To the NE the rocks of this anticlinorium dip beneath the Tibetan Zone, and there we expect to find the roots of the Crystalline Nappe. From HAYDEN's descriptions (1904, p. 9) we may assume that — as observed along the length of the Tibetan Zone — also in Lahoul the metamorphism of the Crystalline dies away in the overlying sedimentary successions.

At the south-eastern end of the anticlinorium in the upper Chandra valley the Tibetan Zone is continuous with the Chamba Synclinorium. NW of the Nun Kun the Tibetan Zone connects with the Kashmir Synclinorium.

Thus we may fairly assume that the sedimentary successions of the synclinoria were originally continuous with those of the Tibetan Zone across the Zanskar Anticlinorium.

The Kashmir- and Chamba Synclinoria show open folds comparable to the structure of the Tibetan Zone of Dolpo (FUCHS, 1967).

A significant observation made in Chamba, as well as in Kashmir, is that the high grade metamorphic series underlying the synclinoria, are missing in the frontal portions of the Crystalline Nappe (Fig. 3). There are two possibilities of explanation:

1. The Crystalline Nappe represents a huge recumbent fold, the core of which is formed by the high grade metamorphic complex. The latter is missing in the apex of the fold.

2. In thrust sheets it is frequently observed that the younger formations are enriched in the frontal portions, whereas the underlying older series are kept behind near the roots. This is an effect of friction.

There is no indication of an apical bending in the frontal parts of the unit. The Chail — granite-gneiss complex of the Dhauladhar Range is different from the Tanols of the Crystalline Nappe of Chamba — Pangi, and can not be regarded as an inverted limb. In the Parautochthonous Unit we find a normal upright succession (Fig. 3).

Therefore we have drawn the sections (Fig. 3) on the basis of interpretation 2.

5. The Tibetan Zone is composed of a rather complete fossiliferous Palaeo-Mesozoic succession. From the sections and descriptions given by HAYDEN (1904), the zone forms a synclinorium. The vergency of the folds is either SW or NE, which stresses the resemblance to northern Nepal (Dolpo, FUCHS, 1967, Pl. 8).

To the NE the synclinorium is underlain by a metamorphic complex — the Tso Morari — Rupshu Crystalline. Again the contact is gradational (HAYDEN, 1904). The movements, which occurred partly in the form of thrusts, are directed towards NE (BERTHELSEN, 1953).

6. The Indus Flysch is a highly squeezed zone composed mainly of Cretaceous to Eocene flyschoid formations with considerable amounts of basic and ultrabasic volcanic rocks. An outstanding feature of the Indus Flysch is its unconformable contact to various zones — the Rupshu - Morari Crystalline, the Tibetan Zone, the Kashmir Synclinorium and the Nango Parbat Crystalline. A compilative description of that zone is given by GANSSER (1964, p. 75—78).

An account on the tectonics of the NW-Himalayas would be incomplete without a reference to the NW-Himalayan Syntaxis, which is a highly conspicuous structural feature.

All the mountain ranges as well as the structural zones, from the Siwaliks to the Karakorum in the N, make a conspicuous bend from a SE to a SW strike.

This bend is particularly sharp in the Muzaffarabad area, which was studied by WADIA (1931). The N-S course of the Jhelum river follows exactly the axial plane of the syntaxis. There the Murrees are overthrust from the E and from the W and the Parautochthonous Unit becomes much reduced.

However, there are several minor structural bends, which seem related to the syntaxis.

In the area E of Tarbela (Pl. 5) the rock formations of Hazara turn from their NE-SW strike to an E-W or even NW strike, but, soon they again attain the NE-SW strike, as observable in the Gundgur Range. But in the Attock — Cherat Range and in the Nowshera area the strike is persistently E-W.

SE of the NW-Himalaya Syntaxis the sigmoid course of the frontal parts of the Lower Himalayas in the Bilaspur — Mandi area may be cited.

WADIA explained the syntaxis as the bend of the Himalayan ranges around a rigid protrusion of the Indian Shield — the Jhelum spur. This explanation is very reasonable, and it may be applied to the minor structures as well.

Finally we may say that the NW-Himalayas are the most complicated part of that mountain system. A complex palaeogeographic setting resulted in the intermingling of various facies, and in the course of Himalayan orogenesis the arcuate form of the north-western rims of the Indian Shield complicated the structure of the growing mountain range. Inspite of these difficulties to exploration, the NW-Himalayas particularly give the chance to solve the intricate problem of an all-Himalayan stratigraphy, as various facies belts are closely connected there.

Literature

AHMAD, F.: Glaciation and Gondwanaland. — Rec. G. S. I., *86*, (4), 637—674, Calcutta 1960 *).

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

AUDEN, J. B.: Some new Limestone and Dolomite Occurrences in Northern India. — Indian Minerals (G. S. I.), *2*, No 2, 77—91, Calcutta 1948.

BERTHELSEN, A.: On the Geology of the Rupshu District, N. W. Himalaya. — Medd. dansk. geol. Foren., *12*, 350—414, Copenhagen 1953.

BION, H. S., & MIDDLEMISS, C. S.: The Fauna of the Agglomeratic Slate Series of Kashmir. — Pal. Ind., N. S., *12*, 1—55, Calcutta 1928.

BORDET, P.: Recherches géologiques dans l'Himalaya du Népal, région du Makalu. Edit. Cent. Nat. Rech. Sci. Paris, 1—275, Paris 1961.

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

CHILINGAR, G. V., BISSEL, H. J., & FAIRBRIDGE, R. W.: Carbonate Rocks Origin, Occurrence and Classification. — Developments in Sedimentology 9 A, 1—471, Elsevier, Amsterdam-London-New York 1967.

DAVIES, R. G., & RIAZ AHMAD: The Orthoconic Nautiloids of the Kala Limestone and the probable Age of the Swabi Formations. — Geol. Bull. Panjab Univ., *3*, 1—5, Lahore 1963 a.

DAVIES, R. G., & RIAZ AHMAD: Fossils from the Hazara Slate Formation at Baragali, Hazara, West Pakistan. — Geol. Bull. Panjab Univ., *3*, 29—30, Lahore 1963 b.

DAVIES, R. G.: The Orthoconic Nautiloids of the Kala Limestone — a Correction. — Geol. Bull. Panjab Univ., *4*, 105, Lahore 1964.

FRANK, W.: Progressive alpine Metamorphose im Himalaya. — unpublished habilitation thesis University Vienna, Wien 1973.

FRANK, W., & FUCHS, G.: Geological Investigations in West Nepal and their Significance for the Geology of the Himalayas. — Geol. Rdsch., *59*, 2, 552—580, Stuttgart 1970.

FUCHS, G.: Zum Bau des Himalaya. — Österr. Akad. Wiss., mathem.-naturwiss. Kl., Denkschr., *113*, 1—211, Wien 1967.

FUCHS, G.: The Geological History of the Himalayas. — 23rd Int. Geol. Congr. Prague, *3*, 161—174, Prague 1968.

FUCHS, G.: The Significance of Hazara to Himalayan Geology. — Jb. Geol. B.-A., Sondbd. *15*, 21—23, Wien 1970.

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

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

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

FUCHS, G., & MOSTLER, H.: Der erste Nachweis von Fossilien (kambrischen Alters) in der Hazira-Formation, Hazara, Pakistan. — Geol. Paläont. Mitt. Innsbruck, *2* (2), 1—12, Innsbruck 1972.

GANSSER, A.: Geology of the Himalayas. — 1—289, 3 pl., Interscience Publishers John Wiley and Sons Ltd. London, New York, Sydney 1964.

GANSSER, A.: The Indian Ocean and the Himalayas. A Geological Interpretation. — Eclog. Geol. Helv., *59* (2), 831—848, Basel 1966.

GARDEZI, A. H., & GHAZANFAR, M.: A change of Facies at the base of the Jurassic in District Hazara, West Pakistan. — Geol. Bull. Panjab Univ., *5*, 53—54, Lahore 1965.

GRIESBACH, C. L.: Geology of the Central Himalayas. — Mem. G. S. I., *23*, 1—232, Calcutta 1891.

GUPTA, V. J.: The Stratigraphy of the Muth Quartzite of the Himalayas. — J. Geol. Soc. India, *10*, 1, 88—94, Bangalore 1969.

GUPTA, V. J.: A Note on the Stratigraphic Position of the Sirdang Quartzites of the Type Area, Kumaon Himalayas. — Verh. Geol. B.-A., H. 2, 263—264, Wien 1972.

GUPTA, V. J., & BEDI, R. S.: A new fossil find from the Chamba District, H. P. — Bull. Ind. Geol. Assoc., *3*, 31—32, 1970.

HASHIMI, N. H.: Note on the geology of West Liddar Valley, Kashmir. — Himalayan Geology, *1*, 284—287. Delhi 1971.

HAYDEN, H. H.: Geology of Spiti. — Mem. G. S. I., *36*, (1), 1—129, Calcutta 1904.

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

HOLLAND, T. H.: On the occurrence of striated Boulders in the Blaini formation of Simla, with a discussion of the geological age of the beds. — Rec. G. S. I., *37*, (1), 129—135 Calcutta 1908.

JÄGER, E., BHANDARI, A. K., & BHANOT, V. B.: Rb - Sr Age Determinations on Biotites and Whole Rock Samples from the Mandi and Chor Granites, Himachal Pradesh, India. — Eclogae geol. Helv., *64*/3, 521—527, Basle 1971.

KANWAR, R. C.: Himalayas and the Continental Drift. — Verh. Geol. B.-A., H. 2, 265—267, Wien 1972.

LAKHANPAL, R. N., SAH S. C. D., & DUBE S. N.: Further Observations on Plant Microfossils from a Carbonaceous Shale (Krols) near Naini Tal, with a Discussion on the Age of the Beds. — Palaeobotanist, *7*, (2), 111—120, Lucknow 1958.

LATIF, M. A.: Explanatory notes an the Geology of South Eastern Hazara to accompany the revised Geological Map. — Jb. Geol. B.-A., Sd. *15*, 5—20, Wien 1970.

Lexique Stratigraphic International, *3*, Asie, Fasc. 8., Contr. nat. rech. scient. Paris, 1—404, Paris 1956.

LYDEKKER, R.: Notes on the Geology of the Pir Panjal and neighbouring Districts. — Rec. G. S. I., *9*, (4), 155—162, Calcutta 1876.

LYDEKKER, R.: Notes on the Geology of Kashmir, Kishtwar, and Pangi. — Rec. G. S. I., *11*, (1), 30—63, Calcutta 1878.

LYDEKKER, R.: The Geology of the Kashmir and Chamba Territories and the British District of Khagan. — Mem. G. S. I., *22*, 1—344, Calcutta 1883.

MATHUR, L. P., & EVANS, P.: Oil in India. — Intern. Geol. Congr., 22nd Sess., India 1964, 1—85, New Delhi 1964.

MCMAHON, C. A.: *Note on the Section from Dalhousie to Pangi via* the Sach Pass. — Rec. G. S. I., *14*, 305—310, Calcutta 1881.

MCMAHON, C. A.: The Geology of Dalhousie, North West Himalaya. — Rec. G. S. I.,*15*, 34—51, Calcutta 1882 a.

MCMAHON, C. A.: On the traps of Darang and Mandi in the North-Western Himalayas. — Rec. G. S. I., *15*, 155—164, Calcutta 1882 b.

MCMAHON, C. A.: Some notes on the Geology of Chamba. — Rec. G. S. I., *16*, 35—42, Calcutta 1883.

MCMAHON, C. A.: Some further notes on the Geology of Chamba. — Rec. G. S. I., *18*, (2), 79—110, Calcutta 1885.

MARKS, P., & MUHAMMAD ALI, CH.: The Geology of the Abbottabad Area, with special reference to the Infra-Trias. — Geol. Bull. Panjab Univ., *1*, 47—55, Lahore 1961.

MARKS, P., & MUHAMMAD ALI, CH.: The Abbottabad Formation: a new name for MIDDELMISS' Infra-Trias. — Geol. Bull. Panjab Univ., *2*, 56, Lahore 1962.

MARTIN, N. R., SIDDIQUI, S. F. A., & KING, B. H.: A Geological Reconnaissance of the Region between the Lower Swat and Indus Rivers of Pakistan. — Geol. Bull. Panjab Univ., *2*, 1—13, Lahore 1962.

MIDDLEMISS, C. S.: The Geology of Hazara and the Black Montain. — Mem. G. S. I., *26*, 1—302, Calcutta 1896.

MIDDLEMISS, C. S.: Gondwanas and Related Marine Sedimentary Systems of Kashmir. — Rec. G. S. I., *37* (4), 286—327, Calcutta 1909.

MIDDLEMISS, C. S.: A Revision of the Silurian-Trias Sequence in Kashmir. — Rec. G. S. I., *40*, (3), 206—260, Calcutta 1910.

MIDDLEMISS, C. S.: Sections in Pir Panjal Range and Sind Valley, Kashmir. — Rec. G. S. I., *41*, 85—137, Calcutta 1911.

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

MUHAMMAD ALI, CH.: The Stratigraphy of the Southwestern Tanol Area, Hazara, West Pakistan. — Geol. Bull. Panjab Univ., *2*, 31—38, Lahore 1962.

NIYOGI, D., & BHATTACHARYA, S. C.: A note on the Blaini Boulder Beds of the Lower Himalaya. — Himalayan Geology, *1*, 111—122, Delhi 1971.

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

OLDHAM, R. D.: The Sequence and correlation of the Pre-Tertiary Sedimentary formations of the Simla Region of the Lower Himalayas. — Rec. G. S. I., *21,* (3), 130—143, Calcutta 1888.

PANDE, I. C.: Palaeotectonic Evolution of the Himalaya. — Publication of the Centre of Advanced Study in Geology, *3,* 107—116, Chandigarh 1967.

PANDE, I. C., & SAXENA, M. N.: Birth and Development of Himalaya. — Publ. Centre of Advanced Study in Geol., Panjab Univ., *4,* 1—19, Chandigarh 1968.

PASCOE, E. H.: A Manual of the Geology of India and Burma. — 1, 3rd Edition, 1—483, Govt. Press, Calcutta 1950.

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

PETTIJOHN, F. J.: Sedimentary Rocks. — 2nd Ed., 1—718, Harper Bro., New York 1957.

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

POWELL, D., & SAXENA, M.: Tillite horizons in the Chamba Himalayas of Himachal Pradesh, North India. — J. Geol. Soc., *127,* (6), 595—598, London 1971.

RAINA, B. N., & KAPOOR, H. M.: Geology of the Kashmir Himalaya. — (Guide to Excursion). 22nd Intern. Geol. Congr. 1964, 1—19, New Delhi 1964.

SCHÜLLER, A., & YING SZU-HUAI: Das Sinian-System in China. — Geologie, Beih., *8,* H. 7, 697—804, Berlin 1959.

SEWARD, A. C., & WOODWARD, A. S.: Permo-Carboniferous Plants and Vertebrates from Kashmir. — Pal. Ind., N. S., *2,* (2), 1—13, Calcutta 1905.

SHAMS, F. A.: A Preliminary Account of the Geology of the Mansehra Area, West Pakistan. — Geol. Bull. Panjab Univ., *1,* 57—63, Lahore 1961.

SHAMS, F. A.: Kyanite Pseudomorphing Andalusite in Hornfelsed Pelitic Schists of Amb State, West Pakistan. — Geol. Bull. Panjab Univ., *4,* 23—28, Lahore 1964.

SITHOLEY, R. V., SAH, S. C. D., & DUBE, S. N.: Plant Microfossils from a Carbonaceous Shale (Krols) near Naini Tal. — Jour. Sci and Industr. Res., 13 B, 6, 450—451, 1954.

STAUFFER, K. W.: Silurian-Devonian Reef Complex near Nowshera, West Pakistan. — Geol. Soc. Amer., Bull. *79,* No 10, 1331—1350, Washington 1968.

STOLICZKA, F.: Geological Sections across the Himalayan Mountains from Wangtu Bridge on the River Sutlej to Sungdo on the Indus, with an account of the formations in Spiti, accompanied by a revision of all known fossils from that district. — Mem. G. S. I., *5,* 1—154, Calcutta 1865.

TAHIRKHELI, R. A. K.: The Geology of the Attock-Cherat Range, West Pakistan. — Geol. Bull. Dept. Geol. Univ. Peshawar, *5,* (1), 1—26, Peshawar 1970.

TEWARI, B. S., & SINGH, P.: Observations on the Geological Structures and Formations on the Jammu-Srinagar National Highway and the Age of the Fenestella Shales. — J. Geol. Soc. Univ. Saugar, *3,* 9—17, Saugar 1967.

VALDIYA, K. S.: The Unfossiliferous Formations of the Lesser Himalaya and their Correlation. — 22nd Int. Geol. Congr. 1964, pt 11, 15—16, New Delhi 1964.

VALDIYA, K. S.: Stromatolites of the Lesser Himalayan Carbonate Formations and the Vindhyans. — J. Geol. Soc. India, *10,* 1, 1—25, Bangalore 1969.

VALDIYA, K. S.: Simla Slates: The Precambrian Flysch of the Lesser Himalaya, Its Turbidites, Sedimentary Structures and Paleocurrents. Geol. Soc. Amer., Bull. *81,* 451—468, Washington 1970.

VERCHÈRE, A.: On the Geology of Kashmir, the Western Himalaya and Afghan Mountains. — J. As. Soc. Bengal, *35,* p. 89, 1866.

WAAGEN, W., & WYNNE, A. B.: The Geology of Mount Sirban in upper Panjab. — Mem. G. S. I., *9,* 331—350, Calcutta 1872.

WADIA, D. N.: The Geology of Poonch State (Kashmir) and Adjacent Portions of the Punjab. — Mem. G. S. I., *51,* (2), 185—370, Calcutta 1928.

WADIA, D. N.: The Syntaxis of the North-West Himalaya: Its Rocks, Tectonics and Orogeny. — Rec. G. S. I., *65,* (2), 189—220, Calcutta 1931.

WADIA, D. N.: The Cambrian-Trias Sequence of North-West Kashmir (Parts of Muzaffarabad and Baramula Districts). — Rec. G. S. I., *68,* (2), 121—176, Calcutta 1934.

WADIA, D. N.: Permo-Carboniferous Limestone Inliers in the Sub-Himalayan Tertiary Zone of Jammu, Kashmir Himalaya. — Rec. G. S. I., *72,* (2), 162—173, Calcutta 1937.

WAKHALOO, S. N., & DHAR, B. L.: On the Geology of the area in and around Kishtwar, Doda District, Kashmir Himalaya. — Himalayan Geology, *1,* 123—146, Delhi 1971.

WEST, W. D.: The Stucture of the Shali "Window" near Simla. — Rec. G. S. I., *74,* (1), 133—167, Calcutta 1939.

WINKLER, H. G. F.: Die Genese der metamorphen Gesteine. — 1—218, Springer-Verlag, Berlin, Heidelberg, New York 1965.


Plate 1
Geological Map of the North-Western Himalayas
Compiled from various sources and own observations by G. FUCHS, 1974
0
50
100km
35° n. Br.
35°
75°
Nanga Parbat
Indus
Peshawar
Nowshera
Swabi
Tarbela
Abbottabad
Attock
Islamabad
Rawalpindi
HAZARA
KASHMIR
Srinagar
Zanskar Range
Kishtwar
Chenab
PANGI
CHAMBA
LAHOUL
SPITI
Dalhousie
Jammu
Jhelum
Potwar Basin
Salt Range
Beas
Mandi
Sutlej
Bilaspur
Simla
Alluvium, Karewas
Siwaliks (Up. Miocene - Pleistocene)
Murrees, Dagshai, Kasauli, etc. (Miocene)
Subathus (Paleocene - Eocene)
Indus Flysch (Cretaceous - Eocene), ophiolites
Mesozoic successions
Tal Formation (Up. Mesozoic)
Permo - Triassic (e.g. Kalhel); Permian (Zewan S. etc.)
Panjal Volcanics (trap, Agglomeratic Slate, Permo - Carboniferous)
Permo - Carboniferous of Salt Range
Syringothyris Lms., Lipak S., Fenestella Sh. (L.- M. Carboniferous)
Jaunsar - Krol, Shali, Lokhan Fn., etc. (age in dispute)
Muth Qzt. (Devonian), Siluro-Ordovician (Spiti)
Tanols (L.- Up. Palaeozoic) of Crystalline Nappe
Tanols, Chails (age in dispute) of Chail Nappe, Siluro-Devonian carbonates (Swabi, Nowshera)
Precambrian - Lower Palaeozoic geosynclinal formations (e.g. Hazara-, Dogra-, Simla Slates, Haimantas, Cambrian of Kashmir)
Dogra Sl. with minor occurrences of Subathus
Cambrian of Salt Range
Intrusive metagranites
Meso - katametamorphic Crystalline
Thrusts
Faults

Plate 2

CORRELATION OF THE HIMALAYAN SEQUENCES

G. FUCHS, 1970

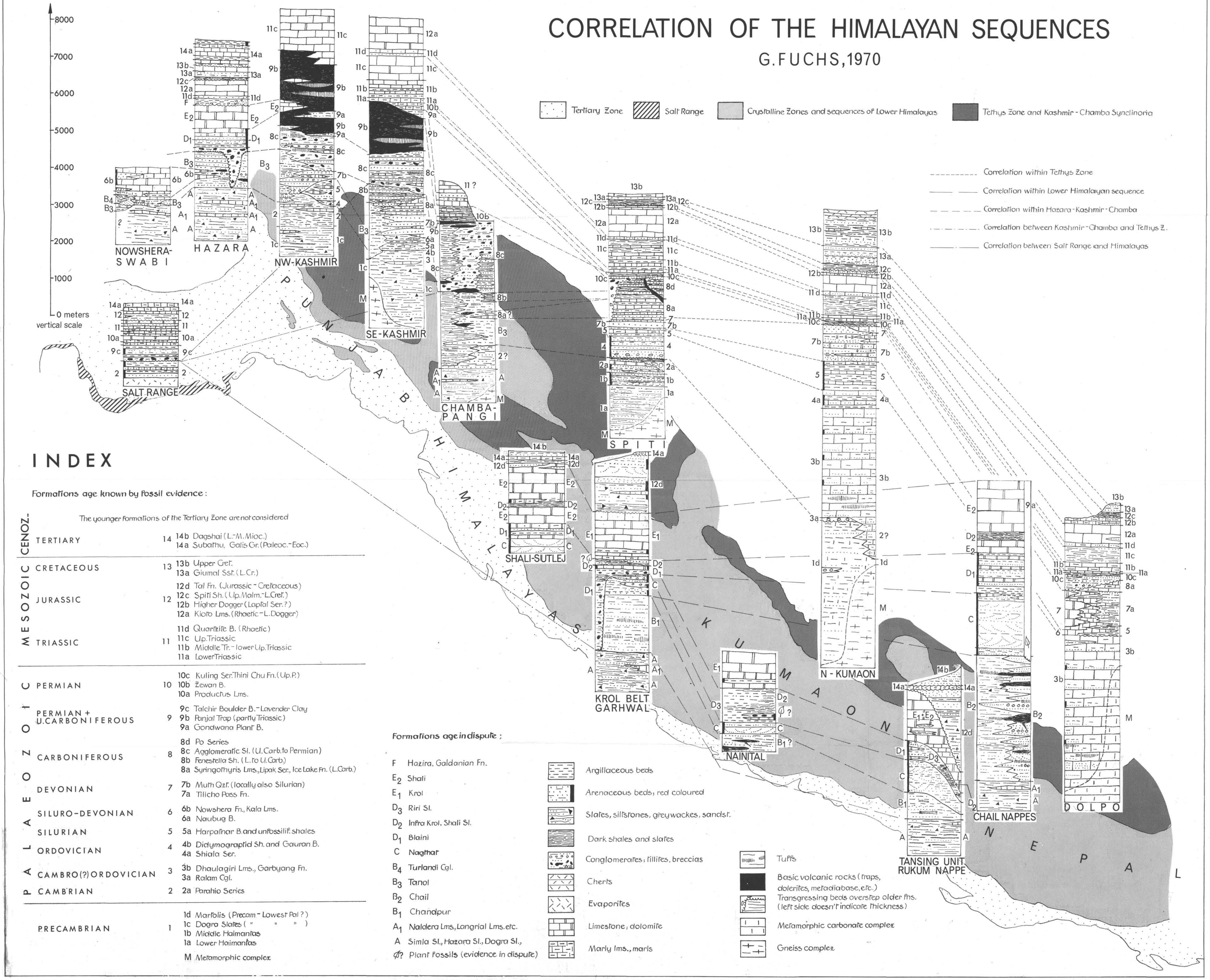


Plate 3

The sections across the Basmai Anticline, Western Liddar valley, Kashmir.
Description in the text. Length of the section ca. 9 km

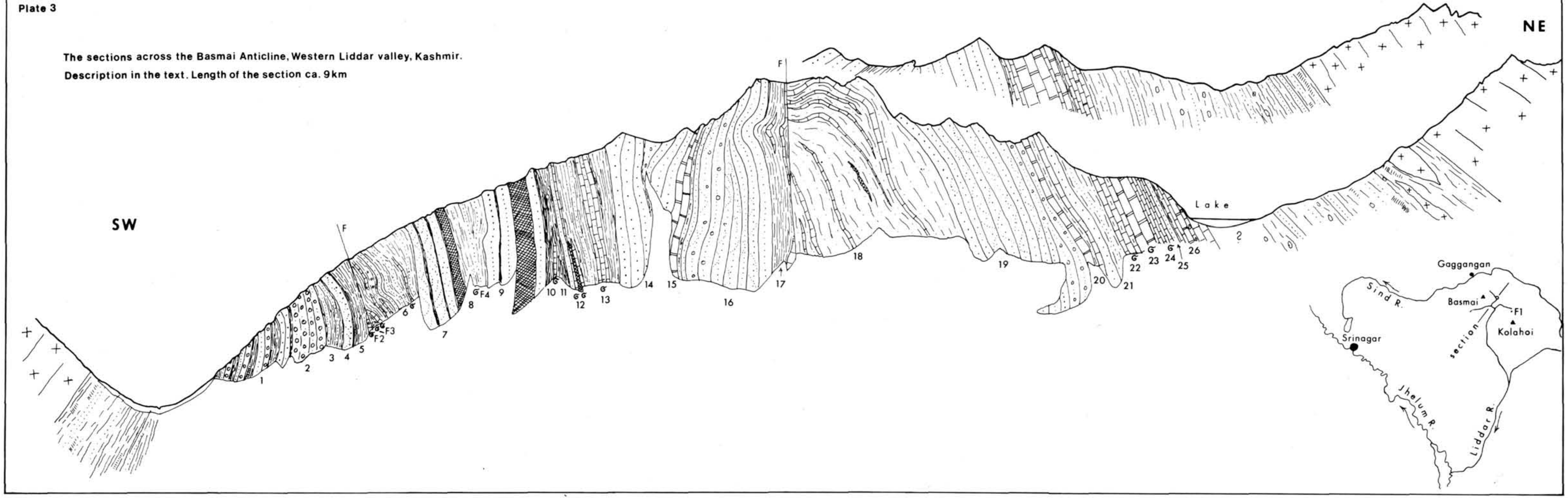
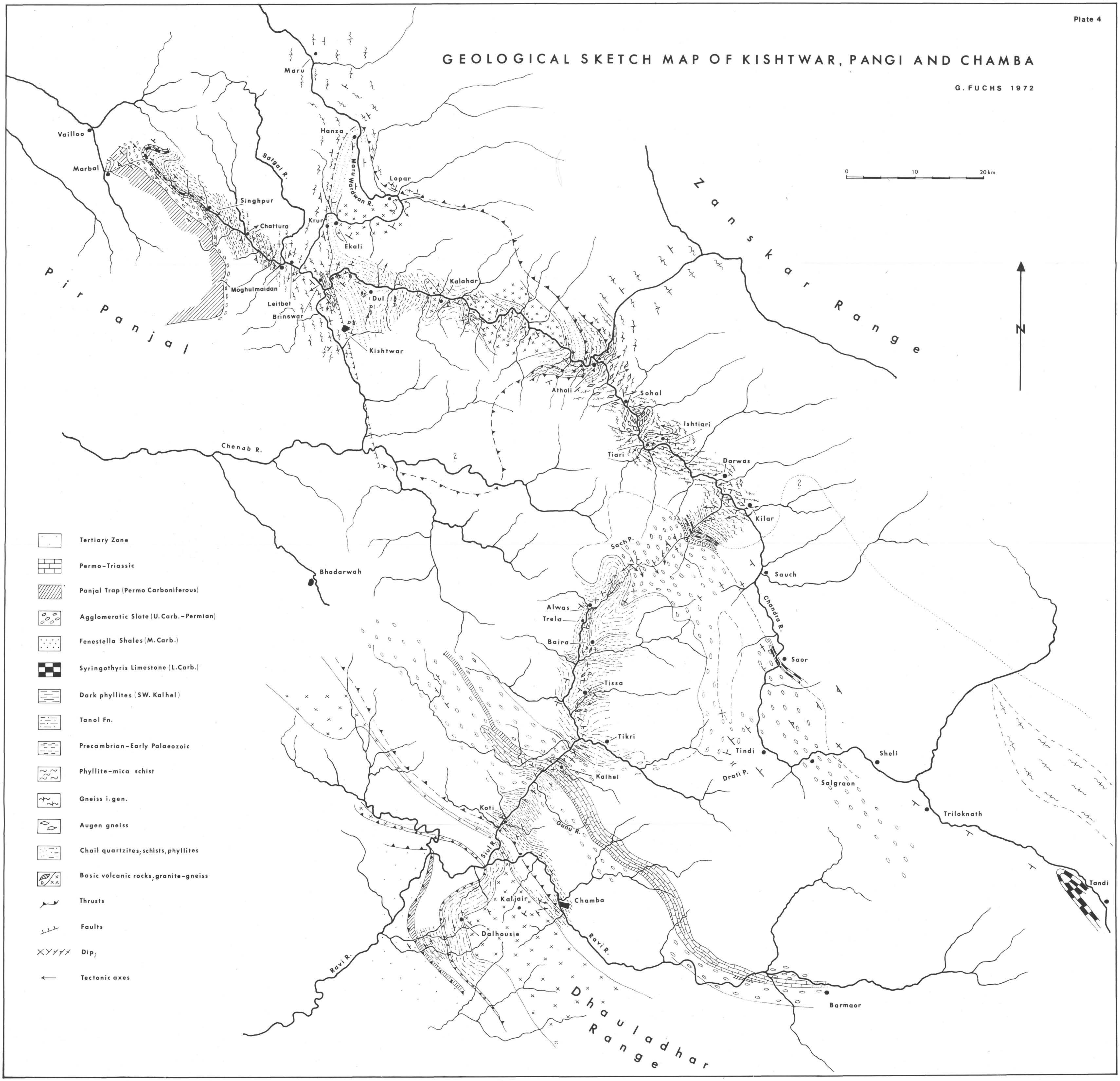


Plate 4

GEOLOGICAL SKETCH MAP OF KISHTWAR, PANGI AND CHAMBA

G. FUCHS 1972



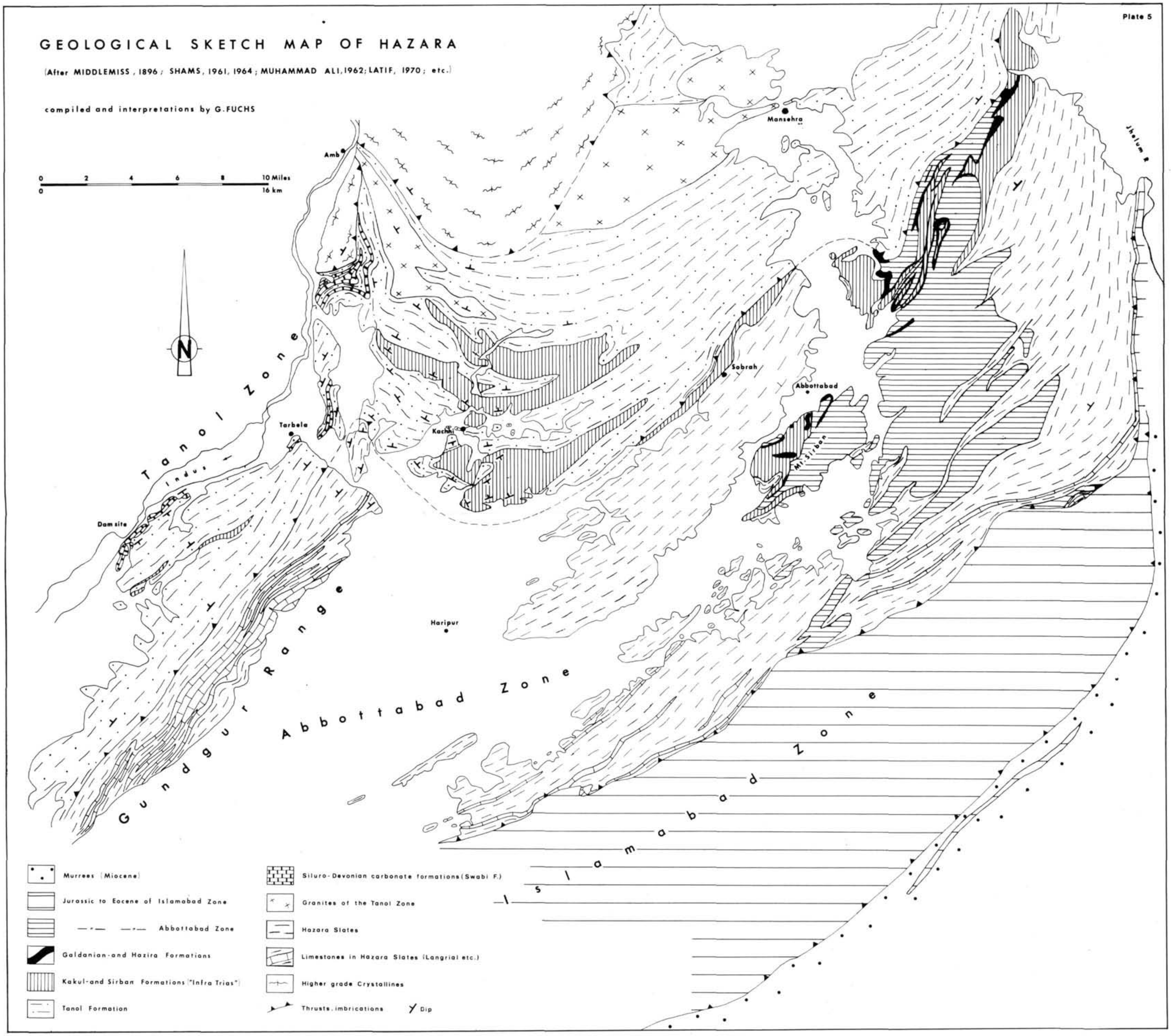


Plate 5
GEOLOGICAL SKETCH MAP OF HAZARA
(After MIDDLEMISS, 1896; SHAMS, 1961, 1964; MUHAMMAD ALI, 1962; LATIF, 1970; etc.)
compiled and interpretations by G. FUCHS
0 2 4 6 8 10 Miles
0 16 km
N
Tanol Zone
Indus
Amb
Mansehra
Jhelum R.
Sobrah
Abbottabad
Mt. Sirban
Tarbela
Kachhi
Dam site
Haripur
Gandgur Range
Abbottabad Zone
Islamabad Zone
Murrees (Miocene)
Jurassic to Eocene of Islamabad Zone
Abbottabad Zone
Galdanian- and Hazira Formations
Kakul- and Sirban Formations ("Infra Trias")
Tanol Formation
Siluro-Devonian carbonate formations (Swabi F.)
Granites of the Tanol Zone
Hazara Slates
Limestones in Hazara Slates (Langrial etc.)
Higher grade Crystallines
Thrusts, imbrications
Dip