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The Geology of Southern Zanskar (Ladakh) – Evidence for the Autochthony of the Tethys Zone of the Himalaya

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With 14 Figures und 3 Plates

Himalaya
Zanskar
Geological Mapping
Stratigraphy
Tectonics

Contents

Zusammenfassung

Die Arbeit ergänzt die bereits von anderer Seite vorliegenden stratigraphischen und paläontologischen Veröffentlichungen durch die Geologische Karte von SE-Zanskar und begleitende Profilserien.

Hinsichtlich der stratigraphischen Entwicklung wird betont, daß der mächtige schiefrig-sandige Basiskomplex der Tibet-Zone eine typische flyschoide Beckenfazies darstellt. Die reichliche, rasche und rhythmische Sedimentschüttung erfolgt in einem instabilen Senkungsraum. Ein orogenes Ereignis, das zeitmäßig mit den kaledonischen Faltungsphasen korreliert wird, bringt einen scharfen Wechsel in der Sedimentation: In epikontinentalem Milieu werden Transgressions-Konglomerate, reife Quarzarenite, Seichtwasser-Karbonate und lokal sogar Evaporite gebildet.

Epirogene Bewegungen an der Karbon/Perm-Grenze führen zu teilweiser Erosion der paläozoischen Formationen und transgressivem Übergreifen des Perm. Diese Diskordanz sowie der begleitende Panjal-Vulkanismus werden mit dem Öffnen der Neotethys in Zusammenhang gebracht. Das im Perm sich bildende Flachmeer bestand im wesentlichen durch das ganze Mesozoikum. Mit der Mittelkreide differenziert sich die Fazies in couches rouges pelagischer Rücken und Plateaus, dunkle pelagische Kalke tieferen Wassers, euxinische siltige Beckenfazies und sandig-tonige Flyschschüttungen. Die vielfältigen Veränderungen der Faziesverteilung in der Oberkreide zeigen Unruhe, und daß der N-Rand des Indischen Kontinents bereits nahe der Indus-Sutur war. Der orogene Umbruch begann in Zanskar erst im Eozän.

Tektonik: Es wird gezeigt, daß das Zentral-Kristallin und die Basisserien der Tethys-Zone eine Einheit bilden, die jedoch lokal wie im Raume von Padam gestört sein kann. Durch eine Achsendepression in Lahoul ist das Zentral-Kristallin dort abgetaucht, Tibet-Zone und Chamba-

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Synclinorium sind in Verbindung. Einzelne Granitstöcke in den Sedimentserien von Lahoul stammen wohl aus dem darunterliegenden Kristallin, sind aber mit diesem nicht identisch.

Die von BAUD et al. (1982a,b, 1983, 1984) und GAETANI et al. (1985) vorgeschlagene Gliederung der Tibet-Zone in einen Stapel von Decken wird mit folgenden Argumenten abgelehnt:

1) Im Stirnbereich der „Decken“ kann an den angenommenen Überschiebungen in einigen Fällen der ungestörte Primärverband nachgewiesen werden.
2) Der „Deckenstapel“ in S-Zanskar entspricht der normalen stratigraphischen Abfolge vom Präkambrium bis ins Unter-Eozän. Lokal gestörte Formationsgrenzen sind kein Beleg für Deckenbau.
3) Zahlreiche Gänge von Panjal Trap in den paläozoischen Formationen im Liegenden der Panjal Laven zeigen, daß es sich um den primären Untergrund und nicht um fremde tektonische Einheiten handelt.
4) Viele der angenommenen Deckengrenzen erweisen sich bei seitlicher Verfolgung als lokal gestörte Gesteinsgrenzen, durchscherte Faltenschenkel oder Schuppungen.

Für tektonischen Ferntransport fehlt somit jeglicher Beleg, und die Tibetische Zone ist in Bezug auf ihren Kristallin-Untergrund sowie ihren Innenbau als autochthon zu betrachten.

Abstract

The paper presents the Geological Map and Sections of SE-Zanskar, a supplement to the stratigraphical and palaeontological work done by other authors.

Regarding the stratigraphical development it is stressed that the thick monotonous argillaceous-arenaceous complex forming the base of the Tibetan Zone ist typical flyschoid basin facies. There was rich supply of sediment and rapid, rhythmic deposition in an unstable, subsiding trough. An orogenic event, which is correlated in age with the Caledonian revolution, causes an abrupt change in sedimentation: In epicontinental environment transgression conglomerates, mature quartz arenites, shelf carbonates, and locally even evaporites were deposited.

Epirogenetic movements at the Carboniferous/Permian boundary cause partial erosion of the Palaeozoic formations and transgression of the Permian. This unconformity and the associated Panjal Volcanism are related to rifting and the opening of the Neotethys. The shelf formed in the Permian persisted throughout the Mesozoic. In the Middle Cretaceous the facies becomes diversified: Couches rouges form on pelagic ridges and plateaus, dark pelagic limestones in deeper water, euxinic silty shales in basins, and sandy to shaly flysch in troughs rich in terrigenous detritus supply. The changes in Upper Cretaceous facies distribution indicate instability and that the northern margin of the Indian Continent was already close to the Indus subduction zone. In Zanskar the orogeny began in the Eocene.

Tectonics: The Central Crystalline and the basal complex of the Tibetan Zone belong to the same unit, although their primary connection may be disturbed, such as in the Padam area. In the Lahoul axial depression the Central Crystalline is covered by the sedimentaries, which are in connection from the Tibetan Zone via Lahoul to the Chamba Synclinorium. There are several granitoid intrusions in the sedimentary series of Lahoul; their source may be in the underlying crystalline complex, but they are not identical with the Central Crystalline.

The suggestion that the Tibetan Zone represents a pile of nappes (BAUD et al., 1982a,b, 1983, 1984; GAETANI et al., 1985) is rejected:

1) In the frontal portions of the "nappes" several of the "nappe boundaries" show undisturbed primary contacts.
2) The assumed pile of nappes in southern Zanskar corresponds to the normal stratigraphic Precambrian–Lower Eocene sequence. Locally disturbed formation boundaries are not evidence for nappe structure.
3) The numerous dikes of Panjal Trap, which penetrate the Palaeozoic formations underlying the Panjal flows, prove that these series represent the primary substratum of the volcanics – they are not another tectonic unit.
4) Many of the assumed nappe boundaries turn out to be just locally disturbed formation contacts, sheared fold limbs, or wedge structures, if traced along the strike.

Thus there is no evidence for thrusts over large horizontal distances in the Tibetan Zone. Also in respect to the underlying Central Crystalline the Tibetan Zone is autochthonous.

1. Introduction

The complicated tectonic belt along the Indus – Yarlung – Tsangpo was difficult to access for many decades. So, when India opened Ladakh for tourism, there began a rush of geological parties from many countries to this region. The investigations concentrated on the flysch- and molasse zones, ophiolite belts, and the melanges. I was particularly interested in the relations of the named zones to the Tibetan (Tethys) Zone with the aim to reconstruct the original facies pattern along the margin of the Indian Continent. 1976 on my first traverse of western Zanskar I discovered the Spongtang Klippe (FUCHS, 1977b) at a place where LYDEKKER (1883) has indicated the occurrence of traps amid of the Mesozoic sedimentaries. 1980 I mapped western Zanskar and came to the conclusion that in the Spongtang area thrust sheets derived from the Indus Zone rest on the autochthonous to parautochthonous series of the Tibetan Zone. French geologists (BASSOULLET et al., 1978, 1980, 1983) active in the same region accepted the northern carbonate belt of Zanskar as a higher nappe ("Zanskar-Shillakong Nappe"). After further studies there is agreement now that the area in question forms a fan-shaped anticlinorium as suggested by me (1977b, 1979, 1982b).

BAUD et al. (1982a,b; 1983, 1984) started work in eastern and southern Zanskar and arrived at the sensational result that the whole of the Tibetan Zone represents a pile of nappes. As this allochthony concept was in contradiction to all my experience from northern Nepal, Spiti, and Kashmir, I visited the Markha–Nimaling area in 1983. To my surprise I found that facies belts bordering along tectonic planes in western Ladakh (Lamayuru Unit – Zanskar Carbonates) are still connected in eastern Ladakh. Thus the original transitions of facies from the shelf to the basin and to the subduction Zone in the N are still recognizable there. The partly metamorphic sedimentary series overlying the Tso Morari Crystalline in the Nimaling Dome represent the sequence of the Tibetan Zone ranging from the Precambrian to the Paleocene (FUCHS, 1984a,b; 1986). All that contradicts BAUD et al., who assumed a series of nappes there. STUTZ & STECK (1986) observed strong deformation and shearing in the Nimaling sequence and therefore follow BAUD assuming the existence of a Langtang Nappe. Certainly the sequence is disturbed, but in my view it is the chronological succession and not a pile of tectonic units.

Admittedly there may be some ambiguity to discern whether a disturbed sequence is stratigraphic or tectonic, because nappes can show similarities and close relations near their root zone (e. g. parautochthonous Helveticum and Helvetic Nappes in the Alps).

In their frontal portions, however, nappes should be distinct from each other and from their autochthonous base. Therefore in 1985 I went to southern Zanskar, where BAUD and his co-workers describe the front of their nappes. There it should be possible to clarify the problem whether the Tibetan Zone was allochthonous or not.

After the first reconnaissance work by STOLICZKA (1865) and LYDEKKER (1883) geological research in southern Zanskar was not taken up again before the seventies of this century. A series of reports were presented by Indian parties (NANDA & SINGH, 1976; NANDA et al., 1978; RAINA & BHATTACHARYYA, 1977; KANWAR & AHLUWALIA, 1979; KANWAR & BHANDARI, 1979; JOSHI & ARORA, 1979; SRIKANTIA et al., 1980). GUPTA describes many fossil finds from this area (GUPTA & RAVI KAUL, 1975; GUPTA & WEBSTER, 1980; GUPTA & JANVIER, 1981; GUPTA & MICHALIK, 1981; GUPTA & SHAW, 1981, 1985; THAKUR & GUPTA, 1983; WEBSTER & GUPTA, 1984; GUPTA, 1981, 1986). The Italian geologists team, partly working together with BAUD, presented a series of detailed accounts on the stratigraphy of southern Zanskar (GAETANI et al., 1980, 1983, 1985, 1986; BAUD et al., 1984; NICORA et al., 1984; JADOUL et al., 1984; CASNEDI et al., 1985).

Unfortunately they had no geological map as a basis for their measured stratigraphic sections, only the generalized tectonic sketch map of Zanskar by BAUD. In respect to the general geology of Zanskar the stratigraphers followed the views of BAUD (BAUD et al., 1982a,b; 1983, 1984; GAETANI et al., 1986). According to this concept the observed sequence of formations ranging from the Precambrian up to the Paleocene is seen as a pile of "nappes". The fact that these "structural units" are found in the original stratigraphic order is explained by the assumption of decollements.

Thus the present situation is the following: There exists a lot of new stratigraphic information, but no adequate geological map – only the sketch map by NANDA & SINGH (1976). Therefore I understand my work as complementary:

1) The geological map (Pl. 1) and the geological sections (Pl. 2) presented in this paper give the frame for the stratigraphic knowledge already existing.
2) Careful examination of the critical parts of the sections, where BAUD et al. assume their nappe boundaries, shall clarify the problem of tectonics, which is a principal one concerning the entire Tethyan Zone of the Himalaya.
3) Investigation of the facies development in the Cretaceous of southern Zanskar may help to complete our knowledge of the palaeogeography just before the beginning of the Himalayan orogenesis.

2. Stratigraphy

2.1. The Central Crystalline

On our 1985 expedition the Central Crystalline was marginally touched in the Tsarap Valley between Ichar and Padam. There it consists of two-mica augengranite-gneisses, nebulitic migmatites, grey and dark paragneisses (coarse-to fine-grained) containing garnet and sillimanite. This migmatite complex is frequently penetrated by aplite and pegmatite bearing tourmaline. Between Ichar and Padam the highly metamorphosed migmatitic gneisses are overlain by slightly altered argillites and siltites of the Phe Formation. There is a great contrast in metamorphism and it is clear that the two rock units are separated by a tectonic plane, as already stressed by BAUD et al. (1982a) and GAETANI et al. (1985).

E of Ichar, however, the original transitional contact Crystalline/sedimentaries is still preserved: E of the village coarse-grained two-micaschists (±garnet and kyanite) become predominating, the gneisses gradually disappear. Then further E the micaschists pass into phyllitic micaschists and dark phyllites intercalated with dark grey to violet quartzitic beds. SE of the impressive Syncline of the Karsha Formation near Abnop the phyllitic series grades into phyllitic slates with beds of metasiltstone and metasandstone, and SW of Purni finally the metamorphism dies away. Thus there is a passage from the Crystalline to the sedimentaries of the Tibetan Zone, which from my experience from other regions of the Himalaya may be called a rule (compare also GRIESBACH, 1891, p. 209; HAYDEN, 1904, p. 9–10; HEIM & GANSSER, 1939; GANSSER, 1964, 1983, p. 33; SRIKANTIA, 1981; BORDET et al., 1971, 1975; HONEGGER et al., 1982).

It is of great interest that further E in the traverses from Lahoul towards the N over the Bara Lacha La respectively Shingo La typical Central Crystalline, which can be traced continuously from the NEFA-Himalaya in the E of the Rohtang Pass area in the W, forming the backbone of the Himalaya, is interrupted in Lahoul. There the Rohtang Crystalline plunges towards the NW and the Crystalline of the Brahman-Zanskar Range plunges axially SE. This fact already known to LYDEKKER (1883, see his map) is shown by all later geological maps (e. g. GANSSER, 1964; FUCHS, 1982c). In the axial depression of Lahoul the sedimentary series of Spiti – Zanskar are connected with those of the Chamba-Kashmir Synclinoria. Therefore along the road from the Chandra Valley to Darcha and the Bara Lacha La respectively the Shingo La most of the country rock belongs to the Phe Formation. This thick argillo-arenaceous complex shows varying grades of metamorphism, generally not exceeding greenschist facies. Alteration commonly increases near granitoid intrusions (e. g. Jaspa Granite, Gumboranjan). Sedimentaries younger than the Phe Formation occur in synclines around Bara Lacha La and at Tandi in the Chandra Valley. The rocks of the latter syncline are altered like the underlying series (POWELL & CONAGHAN, 1973).

NANDA & SINGH (1976) termed the Central Crystalline of the Zanskar Range "Suru Formation" and distinguish four members. The uppermost, the Darcha Member actually belongs to the Phe Formation, which is intruded by discordant granites. The Crystalline is separated from the overlying sedimentary series not by a sharp boundary, but by a passage zone. A good portion of the Crystalline consists of altered sedimentaries and the basal parts of the sedimentary succession have suffered slight metamorphism. From place to place the front of metamorphism reached into various levels of the sedimentary column. In Lahoul and eastern Zanskar the alteration dies away in the Early Palaeozoics, whereas in the Rangdum area of western Zanskar it reaches up high into the Mesozoic series. In view of this, it is meaningless to subdivide the Central Crystalline into stratigraphic units, and as said above, it is doubtful where to draw a boundary between Crystalline and sedimentaries. In this paper the high-grade metamorphics and the transitional zone are dealt in the chapter Central Crystalline, the slightly altered sedimentaries and intrusive bodies are described in the next chapter.

2.2. The Phe Formation and Intrusive Granitoids

As the name Phe Formation (NANDA & SINGH, 1976) is in common use, I keep to it, though no doubt the formation is identical with the Haimanta Formation of Spiti (HAYDEN, 1904). The monotonous argillaceous-arenaceous succession attains thickness of at least 2000 m. It consists of thick-bedded green to grey, massive-unstratified or laminated sandstone and siltstones alternating with green to dark grey, finely laminated silty slates and slates occasionally being carbonaceous. The sandstones are predominantly fine-grained, but there are also medium-grained, micaceous sandstones, fine-conglomeratic layers, and clay gall breccias. Petrographically the sand- and siltstones are immature, micaceous subarkoses (CASNEDI et al., 1985). The thick-bedded arenaceous rocks disintegrate to coarse irregular blocks. Characteristic are the laminated rocks with fining up units, current ripple cross laminations, lenticular, irregular, flasery and cross stratifications (fig. 1, 2). Flame structures at sandstone-slate inter-

Fig. 1.
Lamination and graded bedding in block of the Phe Formation. Note the transversal schistosity in the dark pelitic laminae.
N of the Shingo La (cover of photo lens gives the scale).

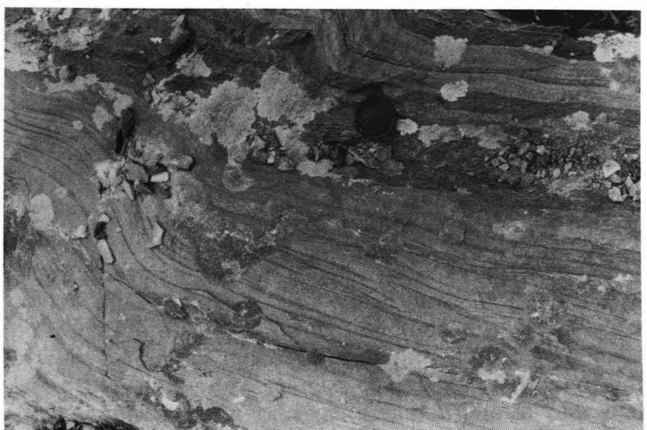

Fig. 2.
Metasandstone to Metasiltstone showing lenticular flaser- and slight cross bedding. Units fining towards the top (near lens cover).
Phe Formation, lower part of the valley leading from Kado Topko Valley to Shingo La.

Fig. 3.
Graded and current bedded metasandstone (light) and metasiltite (dark) ca. 10 km S of Shingo La. Note flame structures in the central part of the photo.

Fig. 4.
Bulbous load convolutions in Phe Formation N of Purni.

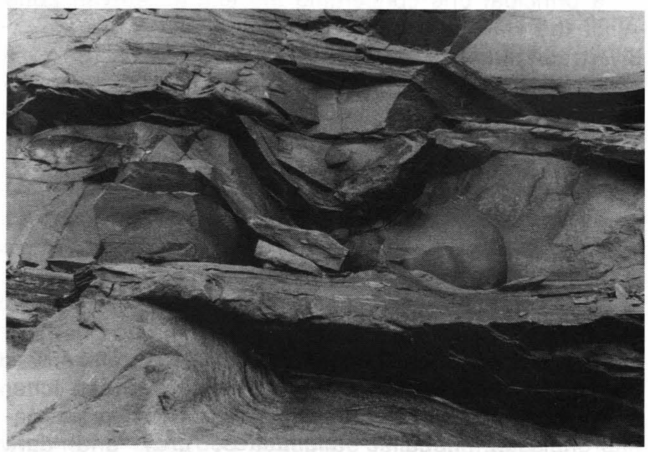

Fig. 5.
Load casts in fine-grained sandstones of Phe to Karsha Formation.
N of Kurgiakh (lens cover for scale).

faces are not rare (fig. 3). Load convolutions ball- and-pillow structures, and beds disturbed by slumping are frequent (fig. 4, 5). Also scour and fill structures are observed. On the s-planes of the sandstones various types of flute casts, rill moulds, groove moulds, burrows and linguoid ripples are found (figs. 6–10). The ripples, which were also reported by BAUD et al. (1984) and CASNEDI et al. (1985), are of a type quite different from shallow-water oscillation ripple marks.

Considering the sedimentary structures, lithology, great thickness and the vast areal extent of this type of formations throughout the Himalaya, deposition in a basin with flyschoid conditions is suggested (SRIKANTIA, 1981; FUCHS, 1982a,b, 1985). Thus I do not agree with BAUD et al. (1984), CASNEDI et al. (1985) and GAETANI et al. (1986), who assume a tidal flat environment with estuarine deposits. This assumption is inconsistent with the large thickness. There was sufficient supply of sediment, which was deposited in a rapidly subsiding instable trough. The areal extent exceeds by far a tidal flat. There are clear indications of activity of turbidity currents in a flysch environment, though these conditions did not persist necessarily throughout the formation (in time and space). The mudcracks and ripples cited as shallow-water indicators (CASNEDI et al., 1985) may be explained as pseudo-mudcracks (DZULYNSKI & WALTON, 1965, p. 167) respectively ripples or sinuous anastomosing pattern of rill moulds (op. cit., p. 59, fig. 43) in a flysch environment.

Fig.6.
Flute casts in flysch sandstone.
Block from upper Phe to Karsha Formation, N of Kurgiakh (lens cover for scale).

Fig. 7.
Bulbous load cast and small flute casts.
Phe Formation S of Char.

Fig. 8.
Flute casts in Phe Formation S of Purni.

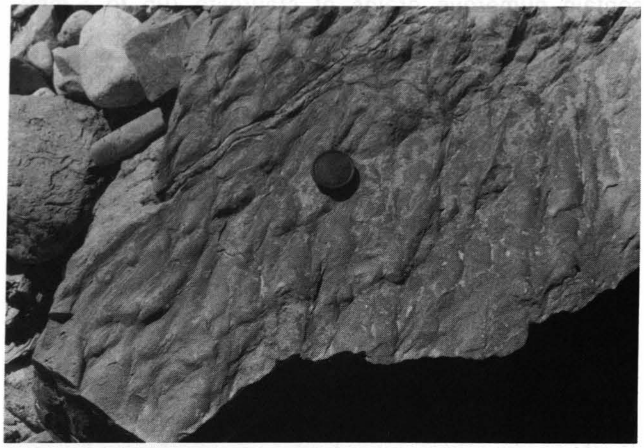

Fig. 9.
Flute casts in the Phe Formation between the villages Yal and Tetha.

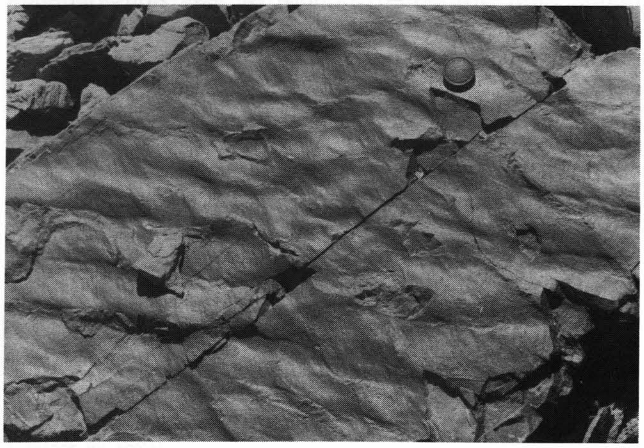

Fig. 10.
Linguoid ripple marks not inconsistent with a flysch environment. The author finds these ripples reminiscent of the "sinuous, anastomosing pattern of rill moulds", fig. 43 in DZULINSKY & WALTON (1965).
Phe Formation between the villages Yal and Tetha.

Tectonics frequently caused small-scale folding or transversal schistosity in the laminated rocks (fig. 1). The grade of metamorphism shows local variation. Epimetamorphic rocks predominate: Phyllitic slates, phyllites, metasandstones and -siltstones. Even if the grade of greenschist facies is exceeded the sedimentary structures are still preserved.

The increase of metamorphism is easily recognized on the descent from the Shingo La to Langkang, which apparently was caused by the Gumboranjan Granite. At the northern foot of the pass the phyllitic rocks pass into phyllitic micaschists. Porphyroblasts of biotite (up to 5 mm thick) grow partly across the s. They are often amoeboid and filled with quartz grains showing internal s, which was partly rotated. Metamorphic minerals are light brown biotite, sericite, clinozoisite and tourmaline. The sedimentary lamination is still preserved. There are also a few layers of amphibolite consisting of coarse-grained, green hornblende, some biotite porphyroblasts, quartz, plagioclase, clinozoisite, apatite and ore; chlorite and sphene are of secondary origin.

E of the Langkang encamping ground, already very close to the Gumboranjan intrusion, the grade of alteration increases. Coarse-grained two-micaschists contain numerous grains of staurolite (up to 5 mm), which enclose quartz and ore; chlorite is secondary after biotite and staurolite. The micaschists bearing small quantities of oligoclase may pass into two-mica paragneiss (±garnet). Both are interbedded with light gneisses of ortho type. It appears that the gneiss-micaschist alternation reflects the sedimentary sandstone-siltstone-slate layering of the Phe Formation. The orthogneisses have granitic compositon: Microcline, somewhat perthitic, oligoclase, quartz, biotite, muscovite, subordinate apatite, garnet, zircon, ore and secondary chlorite. Also in the described micaschist-gneiss series there are some rather rare amphibolitic layers.

The Gumboranjan Granite occurs as a small boss in the centre of a domal structure. It is full of inclusions of the country rock and does not form a homogeneous intrusion rather a network of dikes and sills. First a generation of sills penetrated the country rocks subparallel to their s planes, thus following the domal structure. Then a more or less homogeneous mass of leucogranite intruded into the centre of the dome and swarms of dikes cut the country rock and older sills in all directions. There are quartz-tourmaline veins, and predominating aplites and pegmatites bearing tourmaline, muscovite, garnet, traces of secondary copper minerals and occasional beryl crystals of up to 5 cm length. Frequently the dikes are composite showing banding parallel to the margins. The boundary to the country rock is mostly sharp, in some cases, however, where impregnations occurred, it is not very distinct. The granite in the centre of the intrusion is a fine to medium-grained, light granite to aplite-granite poor in mica. Impregnations with tourmaline are common. A detailed study of the intrusion would reveal several generations of veins and an interesting intrusive history.

As to the age of the Gumboranjan Granite SRIKANTIA et al. (1980) suggested an Early Palaeozoic, whereas GAETANI et al. (1985) prefer a Late Himalayan age judging from the lack of foliation and the composition of the granite. To me these arguments seem very reasonable and I too think that the intrusion belongs to the group of Miocene leucogranites widespread in the Himalayas.

According to GAETANI et al. (1985) the Gumboranjan Granite is faulted along its northern contact, which I did not observe. After crossing the intrusive body the metamorphism dies away, the sills become rare and we are close to the Phe/Karsha Formations contact. Thus the granite intruded in a high level of the Phe Formation.

From Darcha walking up the Kado Tokpo Valley in direction to the Shingo La after ca. 2 km one enters a huge granitoid intrusion. It appears that it represents the direct continuation of the Jaspa Granite, which was dated by FRANK et al. (1976) 495±16 m. a.

With intrusive contact coarse-grained, massive leucogranite, bearing muscovite and tourmaline, borders the only slightly metamorphic Phe Formation, which builds up all the region of Darcha. This marginal facies is followed by coarse-grained two-mica granite containing sporadic, idiomorphic phenocrysts of potassium feldspar (up to 5 cm lenght). There are also irregular dark patches rich in biotite. These patches reach sizes of several cm and seem to indicate contamination. Under the microscope the granite exhibits hypidiomorphic structure. The rocks are almost free of foliation, but may be cataclastic. Perthitic microcline shows idiomorphic phenocrysts with Karlsbad twinning and oriented inclusions of plagioclase. Plagioclase (oligoclase) partly automorphic and zonary, encloses numerous flakes of sericite and patches of carbonate. Quartz frequently is undulaceous. Biotite is brown and contains sagenite and zircon. Muscovite and sericite are rather frequent. Accessory minerals are zircon, apatite, and ilmenite with leucoxen rims.

Such porphyric and slightly hybrid granites build up the area around the place Razik. Further upstream to the tributary coming from Shingo La granitic and granodioritic types are cropping out. In the latter the plagioclase predominates the microcline. It is zonary oligoclase to andesine, partly idiomorphic, and contains sericite and clinozoisite. Brown biotite with some sagenite; asccessories: zircon apatite; secondary minerals: chlorite, clinozoisite, and sericite. The structure is hypidiomorphic.

The granitoid rocks along the Kado Tokpo Valley are rather massive, only occasionally they are foliated. Higher up in the orographically left slopes of the valley the light-coloured granitoids are seen intertonguing with the overlying dark Phe Formation. There are inclusions of the metasiltites in the magmatites measuring dm to several hundred meters, and there are numerous dikes penetrating the sedimentaries (fig. 11). There can be no

Fig. 11.
Granite of the Kado Topko Valley containing enclosure of metasiltite of the Phe Formation.

doubt the contact being intrusive. Besides inclusions of slates and metasiltites also gabbroic and dioritic rocks are found in the granitoids. They are probably rocks from the first stages of differentiation of the magmatic body. There are also fine- and coarse-grained granitoids penetrating each other.

The trail leading up the tributary towards Shingo La crosses the boundary between the granitoids and the succeeding sedimentaries. In the orographically left slope the contact is interlocking in decametric dimensions, on the right side elongate decametric bodies of the magmatites can be seen amidst the metasiltite series. It is evident there that the contact is intrusive and not tectonic as interpreted by GAETANI et al. (1985). These authors mention that the lithology of the sedimentaries "may suggest an affinity with the Phe Formation". However, I should like to stress that it is the Phe Formation, which is continuous there from Zanskar via Lahoul to Chamba. The Tethyan Zone is connected from Zanskar-Spiti to Chamba, thus we are in one tectonic unit not in serveral units making up the "High Himalayan Crystalline" tectonically separated from the Tibetan Zone in the N. The granitoids form discordant intrusions in this vast sediementary complex and do not represent the Central Crystalline (s. s).

In the terrain built up by the Phe Formation metadiabases and metagabbros are occasionally found. These form dikes, up to decamteric dimensions, penetrating the Phe rocks unconformably. They seem to be related with the extrusion of the Panjal Trap (see chapter 1.9.).

Finally the age of the Phe Formation should be discussed. The formation is practically devoid of fossils. NANDA & SINGH (1976, p. 372) refer the finding of trilobites from the upper part of the formation, from their Thonde Member; from this member the authors also mention the occurrence of grey carbonate rocks, thus I infer that the Upper Cambrian fossils are from the Karsha Formation. The Karsha Formation, no doubt, corresponds with the Middle- to Upper Cambrian Parahio Formation of Spiti (HAYDEN, 1904). The underlying Phe Formation correlates to the Haimantas. The Haimantas pass into the Parahio Formation by alternation, as does the Phe Formation into the Karsha Formation. Therefore the Haimanta – Phe complex comprises the Cambrian up to its middle portion and most probably also Upper Precambrian. THAKUR and GUPTA (1983) regard the Phe Formation Cambrian – Lower Ordovician. In my view this is too young because in Spiti the Ordovician conglomerate transgresses on the Haimantas and Parahio Formation with angular unconformity (HAYDEN, 1904; FUCHS, 1982a).

2.3. The Karsha Formation

The name was introduced by NANDA & SINGH (1976) for the thick alternation of argillo-arenaceous and carbonate rocks succeeding on the Phe Formation. These authors assumed Ordovician age, which from the above said is very unlikely. THAKUR & GUPTA (1983) and GUPTA & SHAW (1985) report on ill-preserved trilobite and brachiopod faunas and suggest Upper Ordovician to Lower Silurian age. Like BAUD et al. (1984) I prefer a Middle to Upper Cambrian age from analogy with Spiti.

The lower boundary of the Karsha Formation is not sharply defined. I draw it with the first appearance of carbonate beds. The deposition of flyschoid dark grey to green slates, siltstones, and subarkoses persisted from the Phe into the Karsha Formation. The first carbonate intercalations are thin (up to a few meters) and sporadic, but become abundant in the higher part of the formation. There we find algal reefs up to 200 m thick. The carbonates weathering in bright ochreous colour are predominantly light to medium grey, rarely green-grey dolomite. These very fine-grained to dense rocks are mostly massive and unstratified. However, locally also cm alternation of dolomite and shale was observed; in these cases the carbonate bands were frequently distorted to small scale boudins. The dolomites, particularly the riff complexes, disintegrate to huge irregular blocks. Stromatolites are not rare and figs. 12 and 13, photographs from the top of the formation, show algal colonies resembling bread loaves.

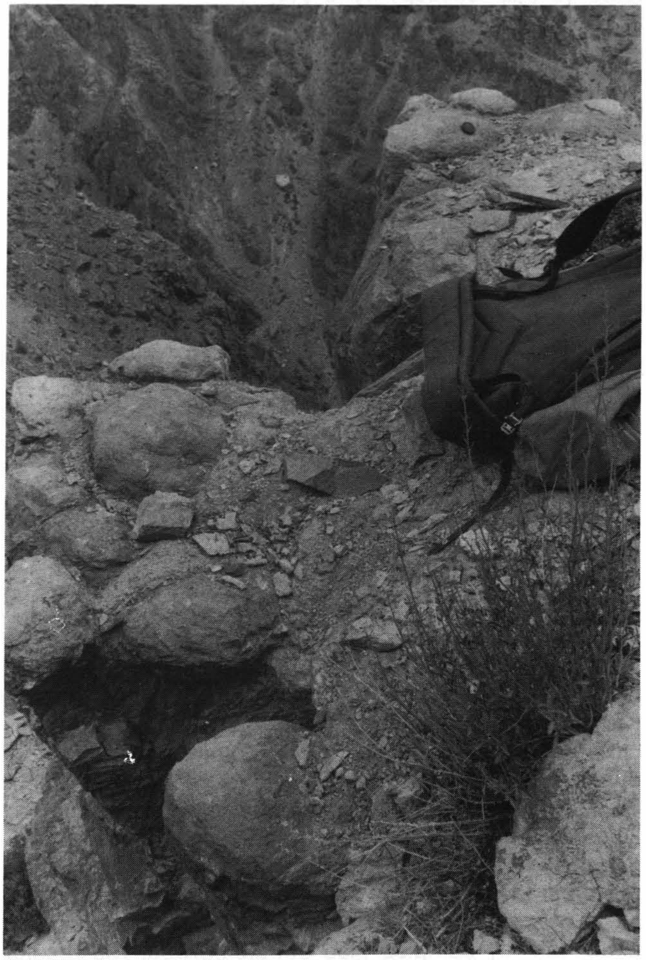

Fig. 12.
Top of the Karsha Formation showing algal colonies resembling bread loaves (rucksack for scale).
ESE of Tanze on the trail to Sinchan.

The flyschoid series interbedded with these shallow-water dolomites consist of green to dark grey and black slates and phyllites, laminated, green, silty slates, siltstones, and fine to medium-grained micaceous sandstones. The latter are partly thick-bedded, partly platey. Sedimentary structures observed are bulbous load casts, burrows, but also ripple marks. CASNEDI et al. (1985) and GAETANI et al. (1986) additionally record

Fig. 13.
Close-up photo of stromatolites of fig. 12 (lens cover for scale).

cross-bedding, mudcracks, bioturbation, patch reefs and peritidal structures. These authors found cycles of shale, sandstone and dolomite and infer an environment of tidal flat to coastal sands and peritidal carbonates. In my view the basin in which the Phe Formation was deposited, was finally filled up. This is shown by the increasing frequency and thickness of the shallow water carbonates. In the uppermost portion of the formation, gradual increase of water depth is indicated (GAETANI et al., 1986).

The thickness of the Karsha Formation is estimated about 800 m by GAETANI et al. (1986), whereas I think that it may exceed 1000 m. There is uncertainty about the primary thickness because of tectonic disturbance. The rigid reefal dolomite bodies within the ductile argillo-arenaceous rocks led to much shearing along the dolomite boundaries.

At Phuktal the top of the Karsha Formation consists of slates, siltstones, light grey sandstones and thick-bedded, fine-grained light quartzites. Such quartzites are not very characteristic of the Karsha Formation, and seem to be confined to the Phuktal area.

In connection with the Karsha Formation it is necessary to mention the occurrence of veins containing ore. In the Surichun Chu thick-bedded dolomite of the Karsha Formation forms the core of a secondary anticline (pl. 1, 2 [16, 17]). These dolomites are discordantly penetrated by serveral veins, up to 1 m thick. Prof. Dr. W. SIEGL (Montan. Univ. Leoben, Austria) kindly has made preparates of my samples and determined the main ore minerals: chalcopyrite, pyrite, and tetrahedrite. By courtesy of Dr. O. SCHERMANN, Dr. H. NEINAVAIE (VOEST-Alpine AG, Eisenerz) kindly examined my samples also by microprobe. His results of two typical samples are presented:

85/11/5: The ore consists predominantly of tetrahedrite, chalcopyrite and subordinate cobalt glance. Pyrite occurs sporadically. Malachite, azurite and Fe-hydroxyds are secondary. The groundmass of the vein is composed of prevailing dolomite and some quartz.
The cobalt glance occurs in xenomorphous to idiomorphous grains, with random distribution in the matrix and as fine inclosures in tetrahedrite; it is also found intergrown with chalcopyrite. Cobalt glance always contains traces of Fe, Cu, and Sb as revealed by microprobe analysis.

85/11/7: The ore consists predominantly of tetrahedrite and pyrite, sporadic chalcopyrite, bornite, and covellite. Secondary ore minerals are azurite, malachite and Fe-hydroxyds. The gangue is composed frequently of quartz (cataclastic and mainly recrystallized) and baryte (particularly associated with tetrahedrite). Pyrite occurs in xenomorphous to idiomorphous grains, which are often cataclastic and replaced by Fe-hydroxyd. The idiomorphous pyrite grains are mostly observed in tetrahedrite. The latter contains small quantities of Fe, Zn and As.
In the above samples the tetrahedrite and chalcopyrite fills interspaces, joints up to 0,2 mm, and the intergranularies of the gangue minerals.

2.4. The Kurgiakh Formation

CASNEDI et al. (1985) and GAETANI et al. (1986) use the term Kurgiakh Formation for a flysch sequence, at least 300 m thick, following on the Karsha Formation. They describe dark bioturbated pelites with layers of nodular dolomite and basaltic tuffs in the lower part. The upper part is a "thickening – coarsening upward megasequence of thin-bedded greenish siltstones characterized by Tb–d Bouma sequences passing upwards to thick-bedded, very fine-grained subarkoses. The Kurgiakh Formation records the transition from shelf and slope sedimentation in poorly oxygenated waters to non-channelized distal turbidites. The sedimentary evolution thus testifies active tectonic subsidence which largely exceeded sedimentation rates" (GAETANI et al., 1986, 447–448). It is symptomatic that this geologist's group has mistaken the above flysch series in the type area for the Phe Formation (BAUD et al., 1984, fig. 8), though these authors deny the flyschoid nature of the Phe Formation.

The Kurgiakh Formation can be traced throughout the Tanze-Chumik-Marpo area as a greenish band on top of the brown dolomite cliffs of the Karsha Formation. The rocks of the Kurgiakh Formation are less resistant than the surrounding formations, thus they form soft terrain frequently covered by talus. I observed green to dark grey, very fine slates and needle shales, frequently laminated, alternating with green to light grey, micaceous sandstones, mainly fine-grained; load casts, rill marks, tool marks etc. are frequent.

This basin facies indicates a renewed subsidence after the shallow-water carbonates of the Karsha Formation. GAETANI et al. (1986, p. 447) report Middle Cambrian trilobites from the lower part of the formation, which shows that this subsidence occurred still in the Cambrian. There is disagreement with GUPTA, who suggests for each formation of the Lower Palaeozoic a considerably younger age (THAKKUR & GUPTA, 1983).

2.5. The Thaple Formation

NANDA & SINGH (1976) introduced this name for a varicoloured, mainly red and brown formation, a marker horizon from the Kurgiakh area of Zanskar to Spiti. The Thaple Formation (some tens to 200 m thick, attaining 300 m in the Chumik Marpo area) is composed of conglomerates, quartzites, sandstones, carbonate sandstones, slates and thin lenses of dolomite. The red, purple and brown conglomerates prevail in the lower part of the formation. They are unstratified to thick-bedded, ill-sorted and contain moderately to well-rounded components up to 30 cm sizes; the latter are varicoloured sandstones, quartzites and slates of the same formation, and dolomites, limestones, phyllites, quartz, greenstone etc. from the beds underlying. The ochreous weathering matrix is arenaceous-calcareous. The conglomerates pass into conglomeratic sandstones, red coarse to medium-grained sandstones, quartzites, carbonate-sandstones and quartzites. Cross-bedding and claygall breccias are very common in these rocks, rarely ripple marks were observed. According to GAETANI et al. (1986) the arenaceous rocks are predominantly litharenites. There are also impure argillites and thin discontinuous cream dolomites. In the orographically left slopes of Chumik Marpo dark haematitic quartzites crop out in the neighbourhood of the Muth Quartzite. As the rocks are vertical along a fault there is some ambiguity whether the rocks belong to the Muth Quartzite or represent Thaple Formation – I favour the last possibility. The hard, thick-bedded quartzites are ill-sorted, moderately to poorly rounded quartzarenites rich in calcareous algae. The latter are frequently replaced by haematite.

In the Kenlung area (Yunan Valley) the Thaple Formation has lost the bright red colour due to metamorphism (greenschist facies).

From the lithofacies and fining-up cycles GAETANI et al. infer a subaerial, alluvial environment of alluvial fan to braid-plain (1986, p. 449). The Thaple Formation marks a break in the sedimentary development: After a long period of flyschoid basin deposition (Phe Formation) a phase of shallowing caused by retarded subsidence (Karsha Formation) and renewed flysch sedimentation (Kurgiakh Formation) the conglomeratic, mainly terrigeneous beds of the Thaple Formation transgress after a gap. In Spiti a marked angular unconformity is found at the base of these conglomerates (HAYDEN, 1904; FUCHS, 1982a). There the purple conglomerates and quartzites pass upwards into a mixed argillo-arenaceous carbonate series, which has yielded Caradocian to Wenlockian faunas (HAYDEN, 1904; REED, 1912). Thus the age of the conglomerates is determined as Ordovician in Spiti. The orogenic phase indicated by the unconformity is further documented by an invasion of granites in the Himalaya dated by FRANK et al. (1976), MEHTA (1977), HONEGGER et al. (1982) and LE FORT et al. (1986). In Zanskar the fossiliferous Ordovician–Silurian sequence of Spiti overlying the conglomerates is missing, however THAKUR & GUPTA (1983) report on crinoids and trilobites from the Thaple Formation (their Tanze Formation). On the basis of these fossils they suggest an Upper Silurian–Lower Devonian age. Similar young age is proposed by GUPTA & SHAW (1985). In my view the break in sedimentation occurred at the same time in Spiti and Zanskar: at the Cambrian/Ordovician boundary. GUPTA's fossils, however, may indicate that the conglomeratic facies persisted for a longer period in Zanskar than in Spiti. Thus the Thaple Formation would represent the Ordovician conglomerates and Quartzites as well as the fossiliferous Ordovician to Silurian sequence of Spiti.

The orogenic event documented by the Thaple Formation is related with the Pan-African orogeny according to BAUD et al. (1984), CASNEDI et al. (1985) and GAETANI et al. (1986). The 550–500 m.a. event in the Himalaya is interpreted by these authors as the last pulse of the Pan-African Orogeny. Thus they disagree with my concept of a Caledonian orogeny (FUCHS, 1967) "on chronological and spatial grounds" (BAUD et al., 1984, p. 184). There is apparently misunderstanding of my views, because I never assumed a connection between the Himalaya and the North-European orogene but correlated in *time*. The granites clustering about 500 m. a. and the Ordovician conglomerates in Spiti–Zanskar mark an initial phase, because in other parts of the Himalaya (Nepal–Kumaun, Kashmir) the basin facies persisted through the Ordovician and the significant facies change took place in the Silurian. The epicontinental Muth Quartzite (Devonian) signals the end of the Caledonian cycle.

2.6. The Muth Quartzite

(STOLICZKA, 1865)

The massive to thick-bedded, white Muth Quarzite is a marker horizon from Kumaun to Kashmir. In the area investigated its thickness varies between 0 and 20 m, occasionally reaching a maximum of 50 m. The primary thickness seems to have been reduced, and by deformation the band of the Muth Quartzite was frequently squeezed and distorted to lenticular bodies (e. g. near Tanze).

The rocks are white to light grey, very hard quartzites, massive or thick-bedded. They disintegrate to large irregular blocks, weathered surfaces being cream coloured. Cross-bedding and oscillation ripple marks are common; burrows were also observed. For petrographic details I refer to GAETANI et al. (1986, p. 449).

In the Chumik Marpo area sporadic beds of ochreous weathering dolomite were found in the Muth Quartzite. Such carbonates accompany the quartzites in Spiti (FUCHS, 1982a), Kumaun (HEIM & GANSSER, 1939) and western Nepal (FUCHS, 1977a).

The Muth Quartzite was deposited in a stable environment with a low rate of subsidence allowing repeated recycling, which led to the superstable composition and high grade of maturity.

Generally the Muth Quartzite is poor in fossils. On the basis of plants and faunas found in different parts of the Himalaya GUPTA (1973) and THAKUR & GUPTA (1983) assigned a Middle to Upper Devonian age.

2.7. The Lipak Formation

(HAYDEN, 1908)

In the investigated area the Lipak Formation consists of grey, dark bluish grey and black limestones, dolomitic limestones, sandy siliceous limestones and marls and light-coloured evaporitic series in the upper part. The thickness varies between 25 and 250 m, probably due to the mobility of the evaporitic rocks. The carbonate sequence is always well-bedded-platey to thick-bedded with even or nodular s-planes. The individual beds often show fine lamination, slightly lenticular stratification and intraformational breccias. Crinoidal limestones and shell beds are very common. The latter contain brachiopods and bivalves.

The rich fossil content of the Lipak Formation is referred by THAKUR & GUPTA (1983) and most recent finds are recorded by WEBSTER & GUPTA (1984) and GUPTA (1986). A *Lower Carboniferous* age of the Lipak Formation is well-established. In the lowermost carbonates following immediately on the Muth Quartzite however, GUPTA (1986) discovered an upper Upper Devonian (Fammenian) conodont fauna. Thus the change from arenaceous to carbonate deposition took place in the uppermost Devonian, similarly to Spiti (HAYDEN, 1904; FUCHS, 1982a, p. 338).

Regarding facies of the carbonates GAETANI et al. (1986) infer a "shallow subtidal environment, possibly an open to restricted carbonate shelf" (p. 451).

The gypsum facies in the upper Lipak Formation is of much interest: It commences with ca. 10 m of blackish limestones alternating with red shales, pink limestones and brown to cream shaly marls. The carbonates are micritic-detrital, pelletal or sandy limestones showing numerous shells of ostracods. GAETANI et al. (1986) record ostracods, crinoids, brachiopods, bivalves, and gastropods from this lower part; one of these fossils *Tomiproductus* ranges in age from Middle Tournaisian to Early Visean.

Then follow basic volcanic rocks and the first gypsum layers. The volcanics are concordantly interbedded, green-grey, schistose rocks. The fabric is fine-grained ophitic with numerous patches of carbonate, which are partly enclosures of the syngenetic carbonates partly amygdales filled with carbonate. Around these carbonate patches the plagioclase laths are arranged parallel to the boundary. The components of the metavolcanics – lavas to tuffs – are idiomorphic plagioclase, chlorite, carbonate, ore, and small quantity of quartz.

Above these volcanics the main mass of white, coarse-grained gypsum follows, several tens of m thick. Interbedded with the gypsum we find pink limestone. These carbonates are micritic-detrital, pelletal, showing strong bioturbation. Crinoidal and algal remains are frequent.

Above the evaporitic series we find well-bedded carbonates like the lower part of the Lipak Formation. There may be a repetition by folding or the facies returned from evaporitic to carbonate shelf conditions near the top of the formation.

2.8. The Po Formation

HAYDEN (1904) introduced this name for the thick shale-quartzite series overlying the Lipak carbonates in Spiti. In the investigated area of southern Zanskar the Po Formation is 200–300 m thick, locally it may attain even 400 m. The formation is a thick-bedded alternation of quartzites, sandstones, siltstones, slates, and impure limestones. The hard quartzites are white, grey, green and break into large irregular blocks. The green, grey, and brown sandstones and subarkoses show current bedding and uneven s-planes. They may contain sporadic mud-supported well-rounded pebbles and cobbles. Greenish siltstones pass over silty shales into black slates, often disintegrating as "needle shales". The dark argillites exhibit bleachig on weathered surfaces. The grey to blue limestones are mostly impure by silt or sand content. Brachiopods, crinoids, and gastropods are sometimes observed. Burrows and other biohieroglyphs are not rare. GAETANI et al. (1986) suggest a shallow epicontinental shelf environment for the lower part of the formation, more proximal deltaic deposition for the upper portions.

Different stratigraphic subdivisions of the Carboniferous are used by SRIKANTIA et al. (1980) and THAKUR & GUPTA (1983). In the present paper the term Po Formation assigns the clastic series between the underlying Lipak Formation and the transgressing Panjal Trap. The conglomeratic quartzites and black slates immediately below the Panjal Trap, however, are excluded from the Po Formation and belong to the transgressing Permian series. This is shown by the fact that the conglomeratic quartzite accompanies the trap irrespectively what formation is underlying.

The age of the Po Formation is Middle and Upper Carboniferous on the basis of the fossil content referred in literature.

2.9. The Panjal Trap

(Ralakung Formation, NANDA & SINGH, 1976)

The dark band of the Panjal Trap is a conspicuous marker horizon in the landscape of southern Zanskar and can be traced also on satellite imagery. The Panjal Trap rests with an angular unconformity on various older Formations (Karsha to Po Formation). This conspicuous unconformity was rightly recognized as stratigraphic by NANDA & SINGH (1976), but recently misinterpreted as nappe boundary (BAUD et al., 1982a,b, 1984).

The base of the Panjal Trap is formed by a 8 to 10 m band of thick-bedded quartzite with partings of black silty argillite. The very hard quartzite is white, green, or grey, fine- to coarse-grained with conglomerate to breccia layers. The components of the latter reach 3 cm sizes and show rounded to angular shapes. They consist of white quartz and dark grey to black quartzite and slate in light quartzitic matrix. The quartzite shows under the microscope angular grains of quartz, fine-grained quartzite, tourmaline, zircon, ore and flakes of white mica in a predominantly siliceous groundmass, which is generally subordinate. The quartzite is moderately to well-sorted, frequently cross-bedded and shows fining up units. The interlayered argillite is black, silty-micaceous shale. At the top just beneath the Panjal Trap the uppermost dms of the sediments are darker and hardened under the influence of the magmatic contact. In thin-section it can be observed that the groundmass has recrystallized with growth of chlorite, sericite, and sphene. In the section NNW of Tanze, where I met the above beds for the first time, the lithology is not so much different from the underlying Po Formation. But I observed that this quartzite band overlapped different beds of the underlying formation. Then I found the conglomeratic quartzites at the base of the Panjal Trap at Phuktal and in blocks in the Thongde area, where the Po Formation is missing. Thus it is evident that the quartzite band marks the Permian transgression so widespread in the Himalayas (W-Nepal, FUCHS, 1967, 1977a; Kumaun, HEIM & GANSSER, 1939; Spiti, HAYDEN, 1904; FUCHS, 1982a). It should be stressed that the lower contact of the quartzite to the Po Formation is a stratigraphic one, the upper to the flows of the Panjal Trap is a magmatic contact, both boundaries being undisturbed by tectonics. BAUD et al. (1984, fig. 2, 10) assumed a thrust separating their Pughtal- and Zangla Units at the base of the Panjal Trap. GAETANI et al. (1986, fig. 5) draw this nappe boundary lower down within the Po Formation or at its base. Actually none of these envisaged thrusts does exist.

The Panjal Trap consists of green basaltic rocks weathering into sharp-edged blocks. According to HONEGGER et al. (1982) the traps are mainly silica-saturated or nepheline normative basalts of the tholeiitic or al-

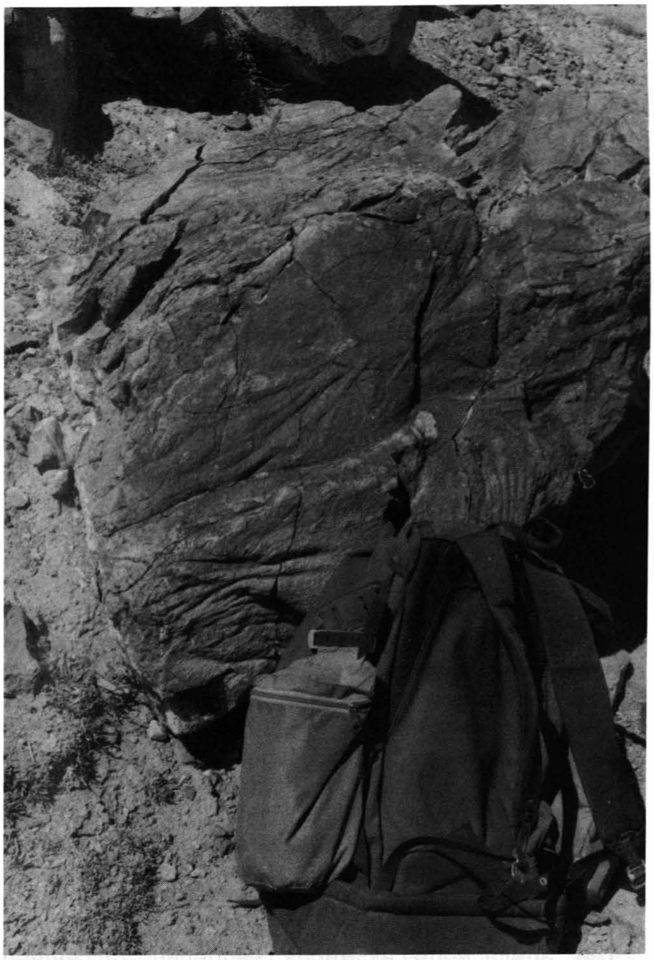

Fig. 14.
Ropy flow structures in block of Panjal Trap, E of Thongde Gompa.

kaline series. There are thick-bedded series of flows showing very fine-grained chilled margins and being medium- to coarse-grained in the central portions of the flow. Pillow structures are sometimes to be found. Vesicular rocks are common, the amygdales filled by chlorite, epidote, quartz, calcite etc. Further cm-wide gas pipes are found perpendicular to the margins of the flow. Structures due to lava flow, such as ropy lava, are not rare (fig. 14). Agglomerates and other pyroclastic rocks are generally multicoloured – red, green, and purple. The components reach dm sizes. Interlayered, and particularly at the top, purple and green tuffaceous slates are associated with the traps. For details of petrography and geochemistry I refer to SINGH et al. (1982) who studied the Panjal Trap of Zanskar particularly.

The thickness of the Panjal Trap in Zanskar – approximately 300 m – is small compared to the thousands of meters in Kashmir. In the Lingti Valley the Panjal Trap pinches out towards the E.

NANDA & SINGH (1976) and SINGH et al. (1982) report on fossiliferous limestones interstratified with the trap. On the basis of the fossils a Lower to Middle Permian age is proved for the Panjal Trap of Zanskar (THAKUR & GUPTA, 1983).

All the older formations underlying the Panjal Trap are penetrated by swarms of basic dikes. Their thickness varies from one to tens of meters. Increased frequency of the dikes near the Panjal Trap, as observed for instance N of Phuktal, shows the connection of the mafic dikes with the Panjal volcanism. GAETANI et al. (1986, 454–455) studied some samples of the mafic dikes and found them to compare well with the Panjal Traps. It is surprising that inspite of these facts BAUD et al. (1984) and GAETANI et al. (1986) think the Panjal Trap as belonging to their "Zangla Nappe" separated by a thrust from the underlying formations ("Phuktal Nappe"), which are cut by the mafic dikes. In my view the observations only allow the conclusion that, when the flows of the trap extruded, the underlying formations were penetrated by numerous dikes from the same magmatic source. Besides the undisturbed contacts this is another evidence that the Panjal Trap forms o n e s t r a t i g r a p h i c succession with the underlying Palaeozoic formations.

2.10. The Kuling Formation

(STOLICZKA, 1865)

The formation varying in thickness between 20 and 50 m is composed of quartzite, sandstone, impure limestone, and silty shales. Thick-bedded white, grey and brown, coarse-grained quartzites dominate in the basal part of the formation. They also contain breccia layers. Associated with the quartzites we find green-grey impure micaceous sandstones. These rocks are succeeded by brown weathering, green-grey, medium-grained carbonate sandstones, -quartzites, grey arenaceous limestones and blue-grey marly limestones and shales. The upper portions of the formation consist of dark silty, micaceous argillites with sporadic black nodules, a series well-known in the Tethys Zone under the name Kuling Shales. NICORA et al. (1984) give a more detailed description of the Kuling Formation, to which I refer.

The Kuling Formation is very rich in fossils and they are found throughout the formation. Brachiopods, bryozoans, corals, gastropods, bivalves, and echinoderms are found. Near the top the first ammonoids occur. The Kuling Formation following the Panjal Trap seems to be mainly Middle and Upper Permian (SINGH et al., 1982) whereas in the E, where the Volcanics are missing, the formation comprises the whole of the Permian (JOSHI & ARORA, 1979; THAKUR & GUPTA, 1983, 15–16). There GUPTA uses the local term Sarchu Series.

The environment of the Kuling Formation was shallow-water. It is a transgressive series like the basal beds of the Panjal Trap Formation. These effusions seem to be related with rifting, which led to the opening of the Neotethys (ANDREWS-SPEED & BROOKFIELD, 1982; HONEGGER et al., 1982). The transgressive sequence of the Permian reflects this break up and the following subsidence (BAUD et al., 1984; GAETANI et al., 1986).

2.11. The Triassic Formations

In western and northern Zanskar the Triassic is represented by an approximately 1000 m thick sequence of limestone, dolomite, and shale. This succession is rather uniform and does not show distinct litho-units suitable for subdivision. It is difficult even to separate the Kioto Limestone from the underlying Triassic beds, if the Quartzite Beds are missing. Additional difficulty to subdivide arises from the tight folding of the sequence. Thus on a reconnaissance survey I used the term Triassic-Jurassic Carbonates (FUCHS, 1982b) or Zanskar-Carbonates (1986) for this series.

In SE-Zanskar, however, the litho-units known from Spiti are more and more recognizable. The subunits are indicated in the map (pl. 1) and sections (pl. 2) in traverses along the Shingri- and Tsarap Chu.

In recent papers the old term "Lilang" has come in common use again. BAUD et al. (1984) and GAETANI et al. (1986) use the name Lilang Group in the sense of HAYDEN (1908) for the Triassic sequence from the base up till the Kioto Limestone. SRIKANTIA et al. (1980) include also the Kioto Limestone. The latter seems preferable to me, because on satellite imagery or by binocular observation from afar the carbonate belt can be traced only as a whole.

2.11.1. The Tamba Kurkur Formation

SRIKANTIA et al. (1980) introduced this name for a very distinct lithounit traceable from Nepal to Zanskar. It is relatively thin, generally less than 50 m – W of the Zanskar River it reaches 100 m according to NICORA et al. (1984) and GAETANI et al. (1986). Composed predominantly of well-bedded limestone the Tamba Kurkur Formation can be followed as a thin resistant band in the scenery.

The formation starts with a thin-bedded alternation of grey, dense limestone and grey shale. Some limestone beds abound in ammonites, which are commonly much deformed. The central parts of the formation are thick-bedded to massive forming escarpments. They consist of grey to bluish, frequently nodular limestone, rather barren in macrofossils. The upper part of the Tamba Kurkur Formation is composed of thick-bedded, dark grey to blue nodular limestones with some shale partings. They are rich in Anisian ammonites. BAUD et al. (1984), NICORA et al. (1985) and GAETANI et al. (1986) show by means of conodont faunas that the Scythian/Anisian boundary is in the upper part of the central member. The Tamba Kurkur Formation comprises the Scythian and Anisian in Zanskar, in Spiti it reaches into the Lower Ladinian accordig to DIENER (1912, p. 71) and KRYSTYN (FUCHS, 1982a).

As to the environment GAETANI et al. (1986) suggest "pelagic sedimentation in upper bathyal condition with low sedimentation rate" (p. 457), which agrees very well with my views (FUCHS, 1967).

2.11.2. The Daonella Shales

At the top the limestones of the Tamba Kurkur Formation become marly and are increasingly interbedded with shale. Thus there is a passage into the succeeding Daonella Shales (ca. 40 m). These consist of soft earthy-coloured shales, marls and dark mudstones, which are generally much contorted and covered by talus. HAYDEN (1904), DIENER (1912) and GUPTA (1975) assign Ladinian age to the sporadic fossils. The Daonella Shales correlate to member 1 of the Hanse Formation of GAETANI et al. (1986). The fossils found by the named authors (p. 459) fit well with this correlation.

2.11.3. The Daonella Limestone

Above the geomorphologically soft terrain of the Daonella Shales the well-bedded Daonella Limestone forms cliffs several tens of meters high. It consists of dark grey, blue, and black limestone partly nodular, and subordinate black marls and shales. The name-giving lamellibranchs are rather frequent (e. g. on the trail from Sinchan to Phirtse La).

In Spiti the Ladinic/Carnic boundary is assumed within this limestone series (HAYDEN, 1904). In Zanskar, however, BAUD et al. (1984) and GAETANI et al. (1986) report Late Ladinic ammonite faunas from the upper part of their member 2 of the Hanse Formation, which corresponds to the Grey Beds of Spiti. Only the lower part of member 2 correlates to the Daonella Limestone. Thus there is ambiguity whether the age of the Grey Beds in Spiti should be revised to be Late Ladinic or a change in lithofacies should be assumed.

2.11.4. The Grey Beds

Above the Daonelle Limestone marly and argillaceous rocks become predominant. Like the two underlying formations the sediments are of dark colour and are bleaching light grey if weathered. The sequence of thin-bedded shales, marls, and limestones is much deformed. The thickness of the Grey Beds – less than 100 m – is much smaller than in Spiti. The Grey Beds are regarded as Carnic in Spiti (HAYDEN, 1904; DIENER, 1912). The lithologically corresponding series in Zanskar has yielded a Late Ladinian fauna (BAUD et al., 1984; GAETANI et al., 1986).

The argillaceous-calcareous sequence succeeding the Tamba Kurkur Formation is deposited on pelagic outer shelf (GAETANI et al., 1986). The uppermost part of the Hanse Formation (member 3) of these authors indicates transition to shallow water carbonate environment. This member 3 corresponds to the lower portions of the Tropites Limestone, which follows on top of the Grey Beds. GAETANI et al., suppose their member 3 to reach into the Carnic, which fits well with the above correlation.

2.11.5. The Tropites Limestone

In Spiti a 250–300 m carbonate succession forms a marked cliff above the soft Grey Beds. HAYDEN (1904) named the series Tropites Beds and I used the term Tropites Limestone (FUCHS, 1982a) for this very distinct litho-unit.

Like in Spiti the Tropites Limestone shows tripartition in eastern Zanskar (Tsarap Valley N of Phuktal):

1) The lowest member consists of dark thick-bedded limestones and dolomites.
2) The middle member is distinctly sandy and weathers in brownish colour. It is composed by a thick-bedded alternation of grey sandy limestones and dolomites, calcareous and dolomitic sandstones, and fine-grained light sandstones and quartzites. Cross-bedding, intraformational breccias, scour and fill structures, oolites, crinoid and shell layers suggest shallow-water deposition. Fine-lamination, partly graded, is common; burrows were observed.
3) The upper member consists of thick-bedded dolomites and limestones.

The Tropites Limestone is approximately 300 m thick and rather poor in fossils. On the basis of the fossils found HAYDEN (1904) and DIENER (1912) regard the Tropites Limestone as Carnic. In the nomenclature of BAUD et al. (1984) and GAETANI et al. (1986) member 3 of their Hanse Formation and their Zozar Formation seem to correlate to the Tropites Limestone. GAETANI et al. found a fauna of megalodontids at the top of their Zosar Formation, which according to them may suggest Noric age. It should be noted, however, that megalodontids occur already in the Carnic. GAETANI et al. (1986) regard the series as regressive, a transition from subtidal inner shelf to interior platform/tidal flat (p. 461).

2.11.6. The Juvavites and Monotis Shales

From Nepal to Kumaun, Spiti, and Zanskar the Noric is characterized by shaly-silty-arenaceous beds being predominant or alternating with limestone: Tarap Shales, Kuti Shales, Juvavites-Monotis Shales etc. From the E towards the W the carbonate content increases and in western Zanskar and Kashmir finally the Noric is calcareous-dolomitic. In the region of the upper Zanskar River the Noric seems to lose its distinct character towards the NW. In parts of Spiti the Noric is divisible into the lower Juvavites Shales and the upper Monotis Shales by a marker horizon – the Coral Limestone (HAYDEN, 1904). Where the latter is missing the lower and upper shale series are difficult to separate. A similar situation is in Zanskar:

The Tropites Limestone is succeeded by a 100–200 m alternation of nodular, partly thick-bedded blue limestone, green, grey to black, silty slates, siltstone, and impure, fine-grained sandstone. Flasery, lenticular stratification, and cross-bedding are common. As to the fossil content I refer to HAYDEN (1904), DIENER (1912), GUPTA (1975), and GAETANI et al. (1986).

BAUD et al. (1984) and GAETANI et al. (1986) designate only one formation – the "Quartzite Series" – between their Zosar Formation (Tropites Lms.) and the Kioto Limestone. Though BAUD et al. (1984, p. 181) refer to HAYDEN (1904) in using the term "Quartzite Series", it is clear from their description that the series comprises both the Monotis-Juvavites Shales (HAYDEN, 1904) and the Quartzite Series (HAYDEN, 1904). GAETANI et al. (1986) discern two litho-zones and it is of great interest that on the top of the lower one they recognized a coral horizon (lithofacies d). It is very suggestive to correlate these "small coral boundstones, occasionally reaching plurimetric size" (p. 462) to the Coral Limestone of Spiti. Thus their lithozone A seems to correspond with the Juvavites Shales, lithozone B with the Monotis Shales. In these series the arenaceous beds are mostly fine-grained subarkoses. The Quartzite Series in the sense of HAYDEN start with the "medium grained quartzarenites with subrounded but moderately sorted grains" below the boundary with the Kioto Limestone (p. 462). To the same horizon BAUD et al. (1984, p. 181) refer by noting quartzarenites "confined to the top of the unit and to the base of the overlying Kioto Limestone". Thus their "Quartzite Series", being ca. 300 m thick, represents HAYDEN's Monotis- and Juvavites Shales and only the uppermost quartzarenites may be correlated to HAYDEN's Quartzite Series. This discussion was necessary to remove the confusion in nomenclature arising from the above use of the term "Quartzite Series".

Regarding environment there is a marked increase in terrigenous influx in the Noric, which may be traced throughout the Tibetan Zone. GAETANI et al. (1986, p. 463) infer "deltaic systems in an inner shelf becoming more diversified upwards (channels, bars)".

Along the strike the facies of the Noric beds changes from flyschoid basin conditions in Nepal to shallow water in the western Himalaya.

2.12. The Quartzite Series

Between the underlying shaly-silty-arenaceous-calcareous alternation and the Kioto Limestone thick-bedded quartzites form a marker horizon throughout the Tethys Himalaya. In Zanskar, however, the Quartzite Series is not as well-developed as in other regions. It is a few tens of meters thick only or may be missing at all in some sections. Characteristic are the thick-bedded quartzites of white, grey, brown, or green colour alternating with brown-weathering carbonate quartzites, blue limestones of Kioto Limestone type and a few shaly beds. The limestone beds may contain large shells of *Megalodon* and *Dicerocardium*. Intraformational breccias and current-bedding are frequent in these shallow-water beds, marking a general regression in the Himalaya. Towards the top the sand content decreases and the Quartzite Series passes into the Kioto Limestone.

The age of the Quartzite Series is generally accepted to be Upper Noric to Rhaetic.

2.13. The Kioto Limestone

(HAYDEN, 1908)

From the Quartzite Series a 500–600 m thick carbonate sequence develops, forming conspicuous cliffs and rock faces. The Kioto Limestone is a thick-bedded succession of grey, blue, and black, partly nodular limestones, grey dolomites, subordinate marls and a few arenaceous layers in the lower part. Many of the dolomites are the product of dolomitization. Oolithic, oncoidal layers, fossil debris, current bedding large scale ripples and intraformational breccias indicate deposition in shallow water. From their facies studies GAETANI et al. (1986) infer a "transgressive-regressive sequence starting with medium to high energy inner shelf environment characterized by bars, channels and small patch reefs. Low to medium energy subtidal inner shelf conditions with poor but differentiated fauna and extensive bioturbation follow. In the middle part of the unit low energy, interior platform conditions are documented. The upper Kioto Limestone is interpreted as medium energy inner shelf with terrigenous supply possibly connected to short term base level fluctuations" (p. 464–465).

The fossils are mainly algae, benthic foraminifers, corals, bryozoa, brachiopods, gastropods, bivalves, and crinoids. Typical are shell beds of *Megalodon, Dicerocardium*, and *Lithiotis*. The age is accepted Rhaetic to Early Dogger.

2.14. The Ferruginous Oolite

Throughout the Tethys Himalaya a thin ochreous weathering band follows the Kioto Limestone and underlies the dark Spiti Shales. This marker horizon of Upper Dogger age was studied in much detail by JADOUL et al. (1985) and GAETANI et al. (1986) in southern Zanskar:

A) The lowest lithozone (0.5–10 m) an oolithic ironstone rich in fossils follows on the Kioto Limestone after a gap, which was larger in the E.
B) Varicoloured shales with scattered belemnites, ammonites, and ferruginous ooids (2–20 m).
C) Cross-bedded bioclastic quartzarenites (<20 m)
D) Fossiliferous oolitic arenites (2–5 m)

The Spiti Shales follow with sharp contact.

The time gap between the Kioto Limestone and the Ferruginous Ooolite (Early resp. Middle Callovian to Late Callovian) spans at least 10 m. a. (JADOUL et al., 1985). During this time deposition continued in other parts of the Tibetan Zone. In Nepal, for instance, the Kioto Limestone grades into the Lumachelle Formation, which in turn is succeeded by a ferruginous impure limestone bed of Callovian age (EGELER et al., 1964; FUCHS, 1967; BORDET et al., 1971). In Kumaun the Laptal Series corresponds with the Lumachelle Formation, and in the Shalshal Cliff the beds between the Kioto Limestone and the Sulcacutus Beds (DIENER, 1912, p. 101, fig. 9). In these regions there may be a slight gap at the base of the Callovian ferruginous bed, in the western Himalaya, however, its time span is obviously larger.

2.15. The Spiti Shales

(STOLICZKA, 1865)

The formation consists of soft, green-grey to black, silty shales with sporadic thin layers of dark impure limestone or siltstone. Dark concretions are not rare. Ammonites and belemnites are frequently found but poorly preserved. GAETANI et al. (1986) observed a layer of fine-grained sandstone and graded calcirudite rich in belemnites and ammonite fragments at the base of the formation. In the same position a belemnite bed is recorded from Spiti (FUCHS, 1982a, p. 351). The Spiti Shales are ca. 20 m thick in western Zanskar, ca. 100 m in the lower Oma Chu, and attain 100 to 150 m in the lower Niri Valley. Due to the soft rocks the Spiti Shales are frequently covered by float and good exposures are rare.

The formation was deposited in deeper water (outer shelf) under euxinic conditions as indicated by the dark sediment colours.

The age of the Spiti Shales is generally accepted as Upper Oxfordian to Lower Neocomian.

2.16. The Giumal Sandstone

(STOLICZKA, 1865)

The Giumal Sandstone shows brown ferruginous weathering colours, by which the formation can be easily traced on satellite imagery. In the region of the Zanskar Valley the Giumal Sandstone consists in its lower part of a thick-bedded sandstone sequence with subordinate pelites interbedded, and an upper part with prevailing dark argillites. The lower part rich in sandstone is approximately 200 m thick in the Namtse La section, 120 m at Zangla; the upper more shaly portion is 80 m in the first, 180 m in the second area. The sandstones and quartzitic sandstones are fine to medium-grained and show grey-green colours. S-planes are often uneven and burrowed and the rocks disintegrate to large irregular blocks. There are also beds of white, green, grey, and black fine-to medium-grained quartzite. The arenites are interbedded with black shales and silty shales, which are often found as clay fragment breccias in the sandstone. In the Oma Chu-Zangla area the uppermost sandstone bed frequently shows dark blackish colour. As I suspected a correspondence with the phosphoritic beds at the top of the Giumal Sandstone in other parts of Ladakh described by FUCHS (1979), BAUD et al. (1982b, p. 355) and GAETANI et al. (1986, p. 468), I gave a sample for chemical examination. Dr. P. KLEIN, Geol. B.-A., kindly informed me that there was a P_2O_5 content of only 0.6 %, Mn 0.06 %, but Fe 23.8 %. Thus the dark sediment colour is obviously caused by iron compounds.

GAETANI et al. (1986) on the basis of detailed studies subdivided the Giumal Sandstone into three parts: the lower one (160–200 m) consists of dark grey sandstones and pelites, the latter becoming prominent towards the E (Tantak). A forams find points to Late Aptian, possibly Albian age. The middle part (110–130 m) is composed of dark grey shales and thin-bedded laminated sandstones. The upper portion (90–100 m) commences with very coarse-grained cross-bedded quartzarenites, followed by pelites, volcanic arenites and biocalciruditic layers with belemnites. Then come black glauconitic sandstones several m thick. As the arenaceous bodies are fining if traced to the E, the middle and upper Giumal are difficult to separate in the Zangla area.

The terrigenous debris comes from the SW from a continental source. It was deposited in deltaic systems, which pass laterally into offshore pelites towards the NE (BAUD et al., 1984; GAETANI et al., 1986; FUCHS, 1986, p. 426). The basic volcanic influence recognized by GAETANI et al. is a problem. Should we accept a local source from basaltic intercalations in the Spiti-Shales recorded by KANWAR & BHANDARI (1979)? Was it basaltic volcanism related to the initial rifting between India and Australia as envisaged by GAETANI et al. (1986, p. 469)? Or should we assume that the northern margin of India was already in a distance from the Indus suture to be influenced by the volcanic arc (Dras) already active then?

The age of the Giumal Sandstone is Upper Neocomian to Late Cenomanian. The upper boundary has become younger by recent ammonite finds (GAETANI et al., 1986, p. 468).

2.17. The Chikkim Limestone and Shillakong Formation

The dark coloured terrain built by the Giumal Sandstone is overtowered by light-weathering carbonate formations of distinct pelagic character. They are either grey or blue – the Chikkim Limestone named by STOLICZKA (1865) – or consist of a varicoloured alternation of limestone, marl, and pelites – a couches rouges facies – termed Shillakong Formation by FUCHS (1982b; synonym Fatu La Formation). In western Zanskar the Chikkim Limestone is confined to the south-western portions of the Tibetan Zone. Towards the N it thins out from 50 m to a few m only. The Shillakong Formation, on the contrary, is missing in the SW and attains several hundred m thickness in the N. Thus in the N the multicoloured facies replaces the grey one. In the transitional zone the Chikkiim Limestone always underlies the Shillakong Formation. This facies change is more abrupt in western Zanskar because the northern parts (N. Z. U.) border the southern parts of the Tibetan Zone along a thrust of a few km displacement (FUCHS, 1982b). E of the Zanskar River this tectonic plane has died away and the northern and southern facies belts are connected. It was my aim to study the facies intertonguing and the way of mutual replacement of the Mid and Upper Cretaceous formations.

The Chikkim Limestone is a well-bedded sequence of grey, rarely blue, partly nodular dense limestone with extensive bioturbation. The rocks are free of terrigenous detritus and full of foraminifera, however ill-preserved. Shale partings are subordinate. The forams determined by R. OBERHAUSER in my samples suggested Cenomanian to Campanian age (FUCHS, 1982b, p. 9). GAETANI et al. (1986, p. 469) were able to define the age of the base as Early Turonian, the top as uppermost Santonian. From their description it is not evident, why these authors assume a hiatus between the Chikkim Limestone and the Kangi La Formation. Contrary I found passage beds yielding a Campanian fauna (FUCHS, 1982b, p. 9).

The Chikkim Limestone was deposited in upper bathyal pelagic environment poor in oxygen and with low rate sedimentation (GAETANI et al., 1986).

The Shillakong Formation (FUCHS, 1982b) consists of an alternation of cream, red, green, grey, and blue limestones and red, purple, green slates and marls. This series is banded in dm to decametric rhythms. Frequently the rocks show fine recrystallization, phyllitic alteration, and transversal cleavage.

The abundant foraminifera are recognized by the unaided eye, but difficult to determine due to recrystallization. In the following I shall describe a series of stratigraphic sections in the region investigated. In southern Zanskar the Shillakong Formation has its westernmost outcrops in the lower Oma Chu, further W it is replaced by the Chikkim Limestone and Kangi La Flysch.

Our westernmost section was measured along the ascent from the Oma Chu to the Haluma La (trail to Lingshet): The boundary between the Giumal Sandstone and the succeeding pelagic limestones is sharp, but tectonically disturbed. In the orographically left slope a wedge of the carbonates is pushed into the upper portion of the Giumal Sandstone. KELEMEN & SONNENFELD (1983, p. 272) seem to interprete this situation as facies intertonguing between the Shillakong Formation and Giumal Sandstone. But without doubt this is a local tectonic reduplication.

The uppermost bed of Giumal Sandstone is almost black, fine- to medium grained sandstone with some cross bedding. In thin section it can be seen that the groundmass as well as part of the quartz grains have been replaced by black to dark brown iron compounds (analyt. kindly by Dr. P. KLEIN, Geol. B.-A., Vienna). With sharp boundary well-bedded, blue-grey limestones follow. Sample 85/38 immediately above the base yielded (all determinations kindly by Dr. R. OBERHAUSER, Geol. B.-A., Vienna*): Strongly recrystallized forams, from their shape highly probable Cenomanian (to Lower Turonian).

Sample 85/36 from the basal blue-grey limestones yielded: *Rotalipora* and *Dicarinella* of an association suggesting Uppermost Cenomanian:

R. ex gr. *cushmanni*
R. ex gr. *deeckei*
Praeglobotruncana ex gr. *algeriana-imbricata*

Approximately 20 m above the base of the carbonates they become multicoloured. Sample 85/39 taken in these beds contains:

Globotruncana ex gr. *sigali-schneegansi*
Age: Turonian (or younger)

The basal grey-blue beds correspond in facies with the Chikkim Limestone the overlying multicoloured limestones are Shillakong facies. Both facies together are 50–100 m thick. At the top the Shillakong Formation is succeeded by dark grey to black marly and silty slates, a ca. 1000 m thick series assigned to the Lamayuru Formation by FUCHS (1982b). Sample 85/40 from their lower part yielded: well-preserved Globotruncanas.

G. arca
G. ex gr. *stuarti*
Age:Upper Campanian (Maestrichtian can not be excluded)

The next section was studied along the ascent to Namtse La from the S: The Giumal Sandstone is succeeded with sharp boundary by blue-grey, thick bedded limestone. Sample 85/32 from the base of the carbonates yielded: abundant small *Thalmanninella, Praeglobotruncana*, and *Globigerina* proving Upper Albian age. This is the only sample free of recrystallization.

8 m above the base the carbonates become multicoloured. The red and green marly limestones exhibit bioturbation. Sample 85/33 contains a poorly preserved fauna, which allows only the identification as Upper Cretaceous.

Sample 85/34 ca. 15 m above the base, rather sheared, yielded *Globotruncana* cf. *coronata* BOLLI. The fauna suggests Upper Turonian to Coniacian age.

In the Namtse La section the Chikkim facies is 8–12 m, the Shillakong facies about 40 m thick. The carbonates are overlain by a several hundred meters thick complex of black slates. A sample 85/35 from the lowest portion of these slates yielded small Globotruncanas, *G.* ex gr. *arca*, suggesting Upper Campanian.

Further E the next section was studied in the gorge N of Zangla: the dark silty slates and siltstones of the upper Giumal Sandstone are followed with distinct boundary by thick-bedded, grey to dark blue limestones with black shale partings. Sample 85/26 taken from the lowest limestone bed yielded abundant, but ill-preserved Rotaliporas and Praeglobotruncanas.

*) Dr. R. OBERHAUSER notes that most of the foraminifera tests (all of them planktonic forms of Middle to Upper Cretaceous age) are strongly recrystallized. Therefore the examinations often had to be based on outer shape and the size, naturally limiting the possibilities of determination.

R. ex gr. *appenninica* (very frequent)
R. cf. *cushmanni* (very frequent)
R. reicheli (rare)
Pr. stephani (frequent)
Age: middle part of Cenomanian

Sample 85/27 ca. 12 m above the base contains ill-preserved planktonic forams. As Praeglobotruncanas are associated with the first double-carinated forms, the sample is from the Cenomanian–Turonian boundary. About 40 m above the base the varicoloured carbonates (85/28) yielded: poorly preserved one keeled and flat double-keeled tests, such as *Globotruncana coronata*. Age: Upper Middle to Upper Turonian (Lower Coniacian can not be excluded).

Sample 85/29 is derived from the core of the syncline: In the schistose rock flat double-keeled forms are just recognizable. The age is probably Upper Turonian–Coniacian.

Sample 85/30 was taken from the lowest multicoloured beds just above the Chikkim facies of the northern limb of the syncline. It yielded undeterminable Globotruncanids.

From the upper Chirche Valley NE of Zangla BAUD et al. (1982b, p. 535) describe a section across the Cretaceous rocks of a syncline NE of the one described above:

The uppermost bed of the Giumal Sandstone – a sandstone with black phosphate nodules – yielded an Albian microfauna. Varicoloured marly limestones showing bioturbation follow (Shillakong Formation). From the lowest bed BAUD et al. recovered an Upper Albian microfauna. Higher up Cenomanian faunas were found in the Shillakong Formation. The change from multicoloured pelagic carbonates to black shale facies occurred in the Upper Cenomanian. The dark series yielded Upper Cenomanian, Upper Turonian and Turonian–Coniacian faunas. The dark shales pass into monotonous marly limestone of brownish colour tentatively related to the Kangi La Flysch (FUCHS, 1979).

The SE continuation of the Cretaceous syncline described above was studied near the village Shade. There the Giumal Sandstone, composed mainly of silty shales, is overlain by blue-grey marly limestone succeeded by black marly slates. Samples 85/41 and 85/42 are derived from the dark basal limestones: The first – lower in the sequence – yielded ill-preserved Globotruncanas.

Rotalipora cf.*reicheli*
Rotalipora ex gr. *cushmanni*
Praeglobotruncana stephani
Age: Probably lower Middle Cenomanian

85/42 contains poorly-preserved partly double-keeled Globotruncanas leaving open Upper Turonian to Campanian age. In the float of the eastern slope of the hill N of Shade I found sporadic rock fragments of red colour, but the Shillakong facies seems to be very subordinate or missing in the Shade area. There the Chikkim facies appears to pass directly into the black shale (Lamayuru) facies. The multicoloured (Shillakong) facies is only locally interbedded.

From the above descriptions it is evident, that the Shillakong Formation from place to place is of different age.

The Shillakong facies seems to start first in the Chirche (BAUD et al., 1982b) and Namtse La areas – in the Albian. Cenomanian faunas are reported by BAUD et al. (1982b), who found the change from couches rouges to black shale facies already in the Upper Cenomanian (Chirche Valley). Very likely these Turonian black shales join up with the black slates replacing part of the Turonian pelagic limestones and marls in the Khurnak area (FUCHS, 1984a, 1986). There Turonian as well as Santonian to Maestrichtian Shillakong Formation are documented. GAETANI et al. (1986) find the formation bracketed between Turonian and Early Campanian in the region W of the Zanskar River. In the northern parts of Zanskar from the Khurnak area mentioned above towards the W (Fatu La) the Shillakong Formation reaches up into the Upper Campanian (BASSOULLET et al., 1978b; FUCHS, 1986) and attains its greatest thickness.

As to the environment it is characteristic that the Shillakong Formation and the Chikkim Limestone are free of terrigenous debris, consisting mainly of planktic foraminiferal remains and pelitic-calcareous muds. The bright colours of the Shillakong formation indicate better oxygenation than the Chikkim Limestone (GAETANI et al., 1986, p. 470). The first appears to be deposited on sills, pelagic plateaus or seamounts (FUCHS, 1982b; GAETANI et al., 1983), whereas, the latter points to deeper less aerated conditions. Both formations are succeeded by thick clastic formations. The Campanian to Lower Maestrichtian Kangi La Flysch follows on the Chikkim Limestone. Its areno-argillaceous material was derived from the S from the Indian Craton. N of this terrigenous basin the pelagic sedimentation persisted on a swell, unaffected by detrital influx. The pelagic facies interfingers with euxinic basin facies (Lamayuru) bordering mainly in the N. With the Maestrichtian the dark silty-pelitic series transgresses the subsiding swell, putting an end to the Shillakong facies.

2.18. The Upper Parts of the Lamayuru Formation

In the last chapter it was described that in all sections the multicoloured Shillakong facies is overlain by black silty argillites. FUCHS (1982b) correlated these beds to the Lamayuru Formation in the N and explained it as an overlap of the basin facies due to subsidence of the pelagic ridge. KELEMEN & SONNENFELD (1983) and GAETANI et al. (1983, 1986) connected these series with the Kangi La Flysch of SW-Zanskar. Though both complexes are flyschoid I felt it necessary to distinguish them for following reasons:

- Lithology: At the top of the Shillakong Formation the red and green colours turn into dark grey to black, but the slates and marls still abound in foraminifers, easily recognizable by the naked eye. Though the formation becomes more silty, it can not compare with the arenaceous Kangi La Flysch. The prevailing rocks are dark grey to black, silty slates bleaching on weathering. The lithology is so similar to the Lamayuru Formation that it is almost impossible to discern the overthrust Lamayuru rocks of the Spongtang Outlier form the underlying series in question, where the separating Tertiary formations (Lingshet Limestone, Kong Slates) are cut out by tectonics.

Contrary the Kangi La Flysch shows ochreous weathering and grey, dark grey and green sediment colours. The rocks are siltstones, silty marls, slates, and thin-bedded sandstones. In the upper portions of the formation sandstones become prominent.

○ Age: By increase of silt and sand the Chikkim Limestone (Upper Santonian) passes into the Kangi La Flysch. The passage beds yielded Campanian faunas (FUCHS, 1982b; GAETANI et al., 1986). The top of the Kangi La Flysch is Maestrichtian (GAETANI et al., 1986) and is succeeded by Upper Maestrichtian – Paleocene shallow-water carbonates (Spanboth Formation).

The Shillakong Formation spans a wide range of time – from Upper Albian to Upper Campanian. It is interfingering with the Lamayuru basin facies in the N. In the SE the basin facies starts to overlap the pelagic carbonates in the Upper Cenomanian (BAUD et al., 1982b) respectively Upper Turonian (sample 85/40), finally putting an end to this facies after the Upper Campanian. The parautochthonous Lamayuru Formation around the Spongtang Klippe yielded only Maestrichtian foraminifers (FUCHS, 1982b). These black pelites are succeeded, possibly after a hiatus by the Paleocene Lingshet Limestone. So the black slates overlying the Shillakong Formation are Upper Cenomanian – Maestrichtian, respectively only Maestrichtian, whereas the Kangi La Flysch is Campanian – Lower Maestrichtian.

For the above reasons I prefer to discern between Kangi La Flysch and the Cretaceous portions of the Lamayuru Formation. The difference to the views of KELEMEN & SONNENFELD (1983) and GAETANI et al. (1983, 1986), however, is not so great. There are transitions between these formations in the Kong-Wakha area of western Zanskar (FUCHS, 1982b) and I do not doubt that they were originally connected. The Kangi La Flysch derived the terrigenous material from the S and has the character of distal flysch deposited in outer shelf to bathyal environment (GAETANI et al., 1983, 1986; BROOKFIELD & ANDREWS-SPEED, 1984). The Lamayuru Formation indicates turbidite deposition on a basin plain or possibly the outer part of a deep-sea fan (BROOKFIELD & ANDREWS-SPEED, 1984, p. 260). I infer that the Kangi La facies was closer to the cratonic source. Its shallowing trend, shown by increase in grain size, led to filling up of a basinal depression in the Zanskar Shelf. The ridge with pelagic carbonate sedimentation N of the mentioned depression was finally transgressed by basin facies after the Campanian. In Maestrichtian times after the subsidence of the swell the site of Kangi La Flysch was connected with the Lamayuru basin in the N. Probably there was a perfect passage between the two flysch facies, but the wedge thrusting S of the Spongtang Outlier interrupted this transition: More northern parts – the Lamayuru Formation of the N. Z. U. – came in touch with the Kangi La Flysch (Tibetan Zone s. s.), thus strengthening facial differences (FUCHS, 1982b).

2.19. The Stratigraphic Evolution of the Tethyan Zone of Zanskar

After the description of the formations occurring in the area studied, an outline of the stratigraphic development is given.

The Late Precambrian – Cambrian formations indicate rich supply of detrital material and rapid deposition in an unstable subsiding trough. The extension of this depositional site was considerable being represented in the whole Himalayas. Montonous series were deposited, thousands of meters thick, partly under flysch conditions. The algal reefs of the Karsha Formation signal a gradual filling up of the basin. The Kurgiakh Formation documents a recurrency of flysch conditions after the foregoing shallowing episode.

The conglomerates of the Ordovician Thaple Formation mark a significant break in the conditions of sedimentation: Long continued basin deposition is followed by continental sedimentation. Along with the angular unconformity in Spiti and the invasion of granites clustering around 500 m. a. an orogenic event is indicated. It is the first phase of the Caledonian orogeny, which phase was active particularly in the western Himalaya. In other parts (Nepal, Kumaun Kashmir) the marked change occurs in the Silurian.

The Devonian Muth Quartzite signals conditions of an epicontinental environment. The supermature quartzarenites indicate a low rate of subsidence and depositon on a stable platform. These stable conditions were brought about by the foregoing Caledonian orogeny. The Lower Carboniferous dark carbonates and gypsum facies suggest deposition on partly restricted inner shelf resp. Sabkha environment (GAETANI et al., 1986).

The Upper Carboniferous Po Formation shows increased supply of continental debris rapidly deposited on the shelf. This indicates a disturbance of the stable conditions prevailing since the Devonian. GAETANI et al. (1986) infer from petrographic data penecontemporaneous basaltic volcanism in progress, which points to beginning rifting.

Thus the Upper Carboniferous sedimentation signals disturbance, which was of epirogenetic type. In Spiti pre-Permian faulting and erosion different from block to block are documented (FUCHS, 1982a, p. 344).

The mapped area is an excellent example for the Upper Paleozic unconformity found in so many areas of the Tethys Himalaya (HAYDEN, 1904; HEIM & GANSSER, 1939; NANDA & SINGH, 1976; FUCHS, 1977a, 1982a, a. o.): The Permian beds transgress over various older formations, from the Po Formation down to the Ordovician. In the area of Tanze the unconformity is an angular one. The Palaeozoic succession complete from the Precambrian to the Upper Carboniferous and dipping ENE at medium to steep angles, is transgressed by the Panjal Trap gently hading NE. Within the short distance of approximately 5 km the post-Cambrian formations disappear towards the NW and the Panjal Trap rests on the Karsha Formation (pl. 2, 3). BAUD et al. (1984) and GAETANI et al. (1985, 1986) interpreted the situation as tectonic overlap of the "Zangla" over the "Phuktal Unit". In the present paper, however, it is shown that the contact between the Po Formation and the transgressive conglomeratic quarztite as well as the magmatic contact of the latter with the succeeding Panjal Trap are both undisturbed. There is no observation suggesting the existence of a thrust. NANDA & SINGH (1976) have given the right explanation as a stratigraphic unconformity.

It is suggestive to correlate the Upper Carboniferous – Permian epirogenetic movements to the extrusion of the Panjal Trap. ANDREWS-SPEED & BROOKFIELD (1982), HONEGGER et al. (1982) a. o. envisage a connection of the Panjal volcanism with continental rifting.

The Permian Kuling Formation like other Permian series (e. g. Thini Chu Formation) is a shallow-water transgressive series. The basal arenites followed by the dark silty Kuling Shales shows the progressive deepening. Important subsidence to bathyal conditions occurs in the Lower Triassic (Tamba Kurkur Formation). The subsidence is unbalanced, because of low supply in sediment. Influx of pelitic material increases in the Ladinian. The environment was pelagic outer shelf with anoxygenic muddy bottom conditions (GAETANI et al., 1986). The Carnian Tropites Limestone was deposited in a regressive phase under shallowing conditions (subtidal inner shelf to tidal flat). The Noric is characterized by subsidence (inner shelf, GAETANI et al., 1986) and increased supply in terrigenous material. These features are found from Nepal to Zanskar. In the latter area, however, the deeper facies influenced by terrigenous debris passes into the carbonate platform of western Zanskar – Kashmir, where the Noric is not very much distinct. The Quartzite Series marks a regression in the Upper Noric–Rhaetic, which affected the entire Tibetan–Tethyan Zone. The following Kioto Limestone (Rhaetic–Lower Dogger) was deposited in rather shallow-waters of a carbonate platform. After a gap the Callovian Ferruginous Oolite transgresses the Kioto Limestone. The formation indicates deposition in shallow water high energy environment with influx of terrigenous material.

The Upper Jurassic to Neocomian Spiti Shales are sediments of deeper water in an euxinic environment pointing to a transgressive phase. The Neocomian to Late Cenomanian Giumal Sandstone shows a marked change in sedimentation: There was rich supply of terrigenous detritus from the craton in the SW. The coarser material was deposited in a deltaic environment (SW-Zanskar). Fining in the NE direction indicates the deepening of the shelf. Phosphates and glauconite are derived from shallow water by multiple reworking. The deposition of the ill-sorted immature rocks was not in a high energy coastal environment (BROOKFIELD & ANDREWS-SPEED, 1984). In my view the Giumal Sandstone is the first signal of the Himalayan orogenesis.

When the supply of terrigenous material ceased in the Upper Albian respectively Upper Cenomanian, pelagic limestones were deposited on the Zanskar Shelf. The Chikkim Limestone (Turonian – top of Santonian) formed in deeper less aerated waters, whereas the multicoloured Shillakong Formation (Upper Albian – Upper Campanian) indicates deposition on ridges, pelagic plateaus etc. These submarine heights remained undisturbed by terrigenous detritus when the Chikkim Limestone became burried under the Kangi La Flysch (Campanian–Lower Maestrichtian). Like the Giumal Sandstone the Kangi La Flysch derived the terrigenous debris from the SW. The clastic sedimentation was triggered by epirogenetic movements in the Indian Craton probably related to first disturbances along the Indus Suture Zone. The dark silty slates (Upper Cenomanian to Maestrichtian) progressively overlapping the multicoloured pelagic limestones are either distal parts of the Kangi La Flysch or Lamayuru Formation. With the Maestrichtian the last pelagic swell areas submerged in the silty, muddy, euxinic basin facies (Lamayuru). This event indicates the subsidence of the northern margin of the Indian Continent coming in touch with the suture zone (FUCHS, 1982b). This submergence was only of short duration – still in the Maestrichtian the southern parts of the Zanskar Shelf became very shallow (Spanboth Formation), in the Paleocene the northern portions of Zanskar followed (Lingshet Lms.). A gap in the Lower Paleocene is inferred by GAETANI et al. (1983, 1986).

The Paleocene shallow-water carbonates are succeeded by multicoloured fresh-water beds – the Chulung La Slates in southern Zanskar, respectively Lower Eocene marine beds, the Kong Slates in central Zanskar. These are the youngest sediments of Zanskar. After their deposition thrust masses slid from the Indus Suture Zone onto the Zanskar Shelf and folding began.

In the area mapped the Upper Maestrichtian Eocene shallow- water series are not exposed.

3. Tectonics

The investigated region of south-eastern Zanskar comprises the marginal parts of the Central Crystalline and the adjoining Tibetan Zone. The latter forms the wide Spiti-Zanskar Synclinorium and we are dealing here with its SW-limb. The relation of the Central Crystalline to the overlying sedimentaries and the problem, whether the sequence of sedimentary formations is stratigraphic or tectonic, were of central interest in this research.

3.1. The Axial Depression of Lahoul

It is a peculiarity of this part of the Himalaya that the northern sedimentary belt (Tibetan–Tethys Zone) exposed in Spiti and Zanskar is connected with the sedimentaries of the Chamba–Kashmir Synclinoria. This is brought about by an axial depression in Lahoul. The Central Crystalline of the Brahman–Zanskar Range plunges towards the SE and reappears in the Rohtang area and the Great Himalayan Range of southern Spiti. The sedimentaries covering the Central Crystalline in Lahoul are mainly the Phe-Haimanta complex. Only locally younger formations are exposed such as in the Tandi Syncline of the Chandra Valley. The alteration of the sedimentaries is mainly greenschist, locally lower grade of amphibolite facies, and the rocks are still recognizable by the sedimentary features preserved.

Like in the Kulu–Rohtang area there are discordant granitoid intrusions also in northern Lahoul (e. g. Jaspar Granite, 495±16 m. a., FRANK et al., 1976). The named granite seems to be connected with the large intrusion of the Kado Tokpo Valley. Large tongues and smaller inclusions of the sedimentaries in the granite and apophyses of the latter document the magmatic contacts. There is no observation supporting the interpretation as a tectonic contact (GAETANI et al., 1985).

On the traverses from the Bhaga Valley in Lahoul to Zanskar via Bara Lacha La or Shingo La it is evident that the silty-phyllitic series of Lahoul are coherent with the Phe Formation of Zanskar. GAETANI et al. (1985) note the "affinity with the Phe Formation" but expect more than one structural unit in the Shingo La section.

In their fig. 1 they draw a thrust plane between the phyllitic series around Darcha and those of the Bara Lacha La and the upper Kurgiakh Valley. Thus they did not realize that the Phe Formation of the latter areas and those of Lahoul ("phyllites") form one unit, continuous even with Chamba.

This connection is a strong argument against the hypothesis of a "Phuktal Nappe" (BAUD et al., 1982a, 1984; GAETANI et al., 1985, 1986). The existence of this nappe would imply allochthony of the Chamba sedimentaries in respect to the underlying Crystalline. However these units are structurally inseparable as shown by FUCHS (1975) and FRANK et al. (1976).

GAETANI et al. (1985) recognized the intrusive nature of the Gumboranjan Granite with the metapelitic wallrocks, its northern contacts, however, they interprete as tectonic. In their fig. 1 the named granite belongs structurally to the "phyllites" of Darcha, the rocks adjoining the granite in the N are designated to the "Phuktal Nappe". Contrary I found no indication of a thrust. The Gumboranjan Granite intrudes the upper portions of the Phe Formation, which shows domal structure with the leucogranite in the core. The sills and dikes are also found in the northern limb of this dome, but there the Phe Formation soon passes into the overlying Karsha Formation.

Thus the region Shingo La – Bara Lacha La – Lahoul is composed of the Phe–Haimanta complex intruded by various granitoid bodies. The sedimentaries are slightly metamorphosed and represent a transitional series between the Tibetan Zone and the Central Crystalline, which is so often observed in the Himalaya. The extraordinary wide extent is a consequence of the Lahoul axial depression. There the Central Crystalline is covered by the weakly altered basal sedimentary series of the Tibetan Zone. The Central Crystalline plunges towards the SE somewhere W of Shingo La. This is the reason why the migmatite complex of the Padam area is lacking towards the SE. The gneisses disappear because of axial plunge beneath the metapelites and not due to overlapping of the "Phuktal Nappe" (GAETANI et al., 1985).

3.2. The Relation between the Central Crystalline and the Sedimentaries of the Tibetan Zone

In the mapped area the Central Crystalline is found only in the W – in the area Padam–Ichar. From Muni to Padam and W thereof the Crystalline consisting of migmatites of high metamorphic grade (sillimanite zone) is overlain by epizonal Phe Formation. The contact certainly is tectonic, as found by BAUD et al. (1982a,b, 1984) and GAETANI et al. (1985). According to them the dip of this structural plane, which is shallow in the Bardan–Padam area, becomes steeper W of Padam. The named authors explain the sedimentaries as a nappe formed by decollements. I doubt that the epizonal sediments came in contact with the crystallines by thrusting from the N over large distances as envisaged by the named authors: Near Rangdum and in the Suru-Kashmir area it is evident that the Palaeo-Mesozoic series of the Tibetan Zone pass into the high grade crystallines – a thrust contact is impossible there (FUCHS, 1977b, 1979, 1982b; HONEGGER, 1983). Also in the Tsarap Valley between the villages Purni and Ichar the metamorphism increases gradually and the transition from the sedimentary series to the Crystalline is almost perfect. Similar passages can be observed in Kashmir, Chamba (FUCHS, 1975), Spiti (GRIESBACH, 1891; HAYDEN, 1904), Kumaun (HEIM & GANSSER, 1939) and Nepal (FUCHS, 1967, 1977a; BORDET et al., 1971, 1975; PECHER & LE FORT, 1986). The fact that the Tibetan Zone is linked with the underlying Central Crystalline in so many places is a strong argument against its allochthony. In its frontal parts a nappe can not become coherent with the underlying units when followed for some distance along the strike. It is easier to explain the observed tectonic contacts as local disturbances. In my view there was generally a transition from the sedimentaries to the Crystalline, which was disturbed by shearing in certain regions. I envisage a mechanism of gravity gliding during the Himalayan uplift similar to the "failles soustractives" reported from the Tibet/Nepal border by BURG (1983). When the Great Himalayan Range was rising, the sedimentary cover was locally decoupled from the crystallines, remained behind, or slumped down along NE-dipping shearing planes. Gravity tectonics are also accepted by PECHER & LE FORT (1986).

In their 1983 paper BAUD et al. speak of a "Ringdom–Phuktal Unit", which consists of a crystalline basement (Tibetan slab), Palaeozoic metasediments and the Late Palaeozoic Panjal Trap (p. 139). Thus BAUD et al. seem to give up the hypothesis of a tectonic separation of the Central Crystalline from the Tibetan sedimentaries.

3.3. The Structure of the Tibetan Zone in SE-Zanskar

The investigated area lies in the south-western parts of the Tibetan Zone. We are here in the marginal portions of the Zanskar Synclinorium, where the sequence from the crystallines up to the Upper Cretaceous is exposed in the SW-limb of this synclinorium. The sedimentary succession, however, is complicated by folding, imbrication and faulting. In my description I shall start in the NW in the Zanskar–Oma Chu area going towards the SE to the Bara Lacha La.

W of the wide Zanskar Valley at Padam the Central Crystalline dips NE at medium angles and is succeeded by the Phe Formation with tectonic contact (pl. 1, pl. 2 [3–5]). The beds of the Phe Formation dip conform with this structural plane, but higher up they show gentle dip towards the NE and even slightly SW hading s-planes. W of Karsha the dip becomes steeper and near the monastery we find steep folding in the rocks of the Karsha Formation. The folded series is followed by gently NE-dipping Panjal Trap (pl. 3). The dark band of the trap cutting the steeply folded Karsha Formation was taken as the base of their "Zangla Nappe" by BAUD et al. (1982a,b, 1984, p. 192) and GAETANI et al. (1985). In my view it represents an excellent instance of the Upper Palaeozoic angular unconformity.

N of Karsha the Panjal Trap is affected by imbrication. The competent and rigid band is broken into three slabs pushed towards the SW into the incompetent Kuling and Lower to Mid Triassic formations. The scale structure is of the order of a few hundred meters only and has nothing to do with nappe tectonics. A little further N – opposite of Thongde – the Panjal Trap is steeply folded with the Permo-Triassic series (pl. 2 [5]). Like in other parts of the Tibetan Zone the folding of competent and incompetent formations led locally to the formation of wedge structures.

Between N Thongde and Zangla both sides of the Zanskar Valley show Triassic–Jurassic carbonates tightly folded. The vergency of the folds varies frequently between SW and NE (pl. 1, 2 [2–6]); the axial planes are generally steep.

At Zangla the Triassic–Jurassic carbonate series are succeeded by Mid-Jurassic to Upper Cretaceous formations, which form an important syncline. This syncline begins E of Zazar and widens towards the NW to a huge synform, in the core of which further W the Spongtang Klippe is found. At its south-eastern end the Zangla Syncline is marked by vertical Spiti Shales. Towards the Zumlung Chu also the Cretaceous series come in, and in the NE-flank we find a steep subsidiary syncline (pl. 1, 2[5]). N of Zangla the Upper Cretaceous black slates come in as the youngest formation in the core of the syncline. They gain large extention around Namtse La. N of Zangla it is obvious that the Triassic–Jurassic carbonates NE of the syncline represent the limb of it and do not form a next higher nappe ("Zumlung Nappe", BAUD et al., 1982b, 1983, 1984; GAETANI et al., 1985). At medium angles the carbonates bend down beneath the younger formations and then become vertical (pl. 2 [4]). They form an anticline between the Zangla Syncline and the syncline of Chirche La (BAUD et al., 1982b, 1983).

NW of Namtse La the NE flank of the syncline becomes overturned and sheared. The Spiti Shales and Giumal Sandstone are cut out and Shillakong Formation and Kioto Limestone come in touch along the "Kangi–Naerung Fault" of KELEMEN & SONNENFELD (1983). This zone of disturbance is the result of different tectonic acts (see FUCHS, 1982b):

1) When the Spongtang Klippe took its place the Jurassic–Tertiary formations were partly sheared off from the Triassic–Jurassic carbonates (decollement).
2) During later compression the limb between the Spongtang Synclinorium and the Honupatta Anticlinorium was overturned and squeezed.
3) The tendency of the Honupatta Anticlinorium to override the Spongtang Synclinorium persisted apparently until Quaternary times. These complications around the Spongtang Outlier are no evidence for a hypothetical "Shillakong–Zumlung Nappe" (GAETANI et al., 1985).

The idea of a "Zanskar–Shillakong Nappe" (BASSOULLET et al., 1983) is abandoned now by the French geologists (GILBERT, 1986; COLCHEN, personal communication 1986).

Certainly the Kangi–Naerung Fault is a major zone of disturbance but not a nappe boundary. This is evident by the fact that the lineament dies out in the SE and the NW. In the Zangla area the shearing of the northern limb of the Zangla Syncline becomes insignificant and it is obvious that the carbonates N of the syncline are part of that fold structure. The stratigraphic sequence from Triassic carbonates up to the Upper Cretaceous black shales is only folded but otherwise undisturbed. In the same way the lineament loses its importance W of Kangi (FUCHS, 1982b). In the upper Wakha Valley the lineament is no more discernible – the series N and S of it form one coherent stratigraphic succession affected only by isoclinal N-directed folding.

Thus the northern limb of the Zangla Syncline is tectonically disturbed from N of Namtse La to W of Kangi. But also the southern flank is sheared. From Zazar to the Zanskar – Oma Chu junction the stratigraphic succession is well-preserved, but in the lower Oma Chu enormous shearing is observed in the Spiti Shales (pl. 1, 2 [1]). There is intensive folding directed SW and the extraordinary thick Spiti Shales are sheared off from their base. This is evident from the many bands and lenses of the Ferruginous Oolite within the Spiti Shales. In my view this decollement is the SE-end of the thrust separating the Tibetan Zone (s. s.) form the Northern Zanskar Unit (N. Z. U., FUCHS, 1982b,c).

The last named unit is a subunit of the Tibetan Zone, a wedge, not a nappe. The maximum displacement should be a few km only. This amount is suggested by facies differences N and S of the thrust: Chikkim Limestone in the S – prevalence of Shillakong Formation in the N; Kangi La Flysch in the S – euxinic flysch (Lamayuru) in the N. Spanboth Limestone in the S – Lingshet Limestone in the N; Chulung La Slates in the S – Kong Slates in the N (see FUCHS, 1982b, Pl. 2A). My correlation of the N. Z. U. Thrust with the disturbed zone of the lower Oma Chu is based on the rich development of the multicoloured pelagic limestones (Shillakong Formation) NE of the tectonic line. This is a characteristic of the N. Z. U., whereas this facies is unknown SW of the thrust in the upper Oma Chu – Spanboth – Kangi La region.

I suppose that the N. Z. U. Thrust like the Kangi–Naerung Fault is caused by the Spongtang Klippe. It develops as a decollement in the lower Oma Chu and dies out in highly deformed Triassic carbonates of the Phulungma Valley. That gives a regional extent of 70 to 80 km along the strike, which is about equal to the length of the Kangi–Naerung Fault. The maximum displacement along the N. Z. U. Thrust seems to be between Photak La and the Chulung Chu, where even the Dras Unit of the Spongtang Outlier comes in contact with the Chulung La Slates of the Tibetan Zone (s. s.) (FUCHS, 1982b, Pl. 1, 2).

The Spongtang Klippe as a rigid mass seems to be responsible for the development of wedge structures SW and NE of it. These reverse faults date back to the compression following the emplacement of the outlier. In this tectonic phase, probably in the Miocene, the Indus Molasse was folded and overthrust from the S, all the tectonic units of the Indus Zone became overturned, and the carbonate belt of northern Zanskar was tightly folded and became fan-shaped (Honupatta Anticlinorium, KELEMEN & SONNENFELD, 1983) N of the Spongtang Outlier (see FUCHS, 1982b, pl. 2).

So my recent mappings in the Zanskar Valley join up with the investigations of my 1980 expedition published in 1982b.

Finally it should be noted that besides folding and imbrications there are also vertical faults. Near Pidmu along the ascent to the Namtse La the trail follows a ENE–WSW trending traverse fault. The northwestern block is subsided along this fault for several tens to a hundred meters. This fault is already recorded by GAETANI et al. (1985).

Now I shall describe the tectonics from the Zanskar River towards the SE.

At Kumi, NE of Padam, the Karsha Formation is isoclinally folded with the overlying Panjal Trap. Bands of Kuling- and Tamba-Kurkur Formations in the upper parts of the Panjal Trap near Thongde show that the great thickness of the Trap is caused by internal folding. The Triassic formations NE of Thongde are folded with steep axial planes and varying direction, like W of the Zanskar Valley (pl. 2 [6]).

Further SE between the villages Ichar and Abnop there is a conspicuous synform in the Karsha Formation N of the Tsarap River. The light colour of the involved dolomites is easily recognized even on satellite imagery. The axis of this steep syncline is directed NE–SW across the regional strike. The cross folding may be related with the axial plunge of the Central Crystalline and the forming of the Lahoul depression (see chapter 2.1.).

SW of Phuktal the dolomites of the Karsha Formation dip at low angles towards the NE. The upper parts of the Karsha Formation are penetrated by numerous discordant dikes of Panjal Trap. Their thickness and frequency increases towards the top of the formation (e. g. N of the monastery). It is evident there that the Karsha Formation represents the original base for the flows of the Panjal Trap. Between the Karsha Formation and the trap there are, however, a few meters of conglomeratic quartzite indicating the Permian transgression just before the effusions of the trap. The outcrops at the new water pipe above the precipices of the gompa show that the Panjal Volcanics follow the underlying rocks stratigraphically and not as the base of the "Zangla Nappe" (BAUD et al., 1982a,b, 1984; GAETANI et al., 1985). There are no observations suggesting a tectonic contact. Contrary the transgressing beds as well as the many dikes of trap in the underlying series document the primary coherence of the sequence. Apparently BAUD et al. (1983) realized that it was not possible to place a nappe boundary between the Karsha Formation and the Panjal Trap and so they assumed the thrust at the top of the Panjal Trap (fig. 2, 138–139). Actually both nappe boundaries are not existing.

The Tsarap Valley N of Phuktal provides a complete section from the Permian up to the Kioto Limestone. The series are folded with subvertical axial plane and are younging towards the NE. Between the knee of the Tsarap Chu and the Niri Chu there are several synclines of Spiti Shales in the Kioto Limestone. These synclines are in the strike of the Zangla Syncline and may be regarded as south-eastern continuation of this fold (pl. 1, 2 [8–12]).

At the junction of the Tsarap and Niri Chu the "Zangla Nappe" is followed by the "Zumlung Nappe" according to GAETANI et al. (1985, Fig. 1). There like further up in the Niri Chu there is no support for the assumption of a nappe boundary. One can only observe the folded succession Kioto Limestone to Giumal Sandstone.

NE of the zone just mentioned we find a major syncline, which is the direct continuation of the syncline of Chirche La described by BAUD et al. (1982b, 1983). From satellite imagery it seems that the NE-limb of the syncline is tectonically disturbed: The light-weathering Upper Cretaceous sediments are immediately succeeded by Triassic–Jurassic carbonates (Pl. 1, 2 [4–7]). In the Shade–Tantak area the shearing was apparently not so strong: Ferruginous Oolite and Spiti Shales come in between the mentioned carbonates and the Giumal Sandstone. Though disturbed the stratigraphic sequence is more complete there (Pl. 2 [8–10]). Also this shear zone was taken as a nappe boundary, between the "Zumlung-" and the succeeding "Khurna Nappe" (GAETANI et al., 1985, fig. 1). Actually the NE-flank of the syncline was somewhat reduced by shearing, which may be called a wedge or imbrication, but there is no indication of a nappe. The Shade–Tsho Tok Phu area shows the syncline consisting of a series of subsidiary folds (pl. 1, 2 [9–12]). The vergency of the folding is SW.

On satellite imagery the syncline may be traced farther SE by the brown colours of the Giumal Sandstone, and the light weathering of the Upper Cretaceous formations. SW of this syncline brownish patches amidst the Triassic–Jurassic Carbonates indicate the occurrence of different rock series, which I would interprete as Palaeozoic formations occurring in an anticlinal zone. However this is speculation.

After the description of the tectonics of the Tsarap region I shall now deal with the Tanze–Kurgiakh area: In the basal formations of the Tibetan Zone there is an interesting structure. Kurgiakh Formation forms the core of a syncline, the flanks consist of Karsha Formation. The axial strike is roughly N–S and the direction of thrust is towards the E. This transverse syncline was described by BAUD et al. (1984, fig. 8, 10, Sect. III) as an imbricate structure: An anticline of Phe Formation should be thrust onto Karsha Formation. The "Phe Formation" is the Kurgiakh Formation, the southern continuation of the type section along the Kurgiakh River downstream of Tanze (CASNEDI et al., 1985). As the named formations both exhibit distinct flysch type, they are easily mistaken. There is no doubt, however, about the synclinal character of the structure. The Karsha rocks of the eastern flank dip W beneath the flysch, and so BAUD et al. (1984) who took this as Phe Formation, assumed a thrust. The W-limb dips E at medium to steep angles, but is overturned near the southern end of the syncline (in the Lunak Valley NW of Kurgiakh Village) (pl. 1, 2 [15]). The syncline crosses the Kurgiakh Valley towards the N, becomes isoclinally dipping E and ends E of Kuru. It is suggestive that the described syncline is a pre-Ordovician fold element, which is cut out by the transgressing Thaple Formation (Ordovician–Silurian). This, however, is difficult to prove, because of the complicated geology of the area:

Besides the unconformity marked by the Ordovician conglomerate there ist the Upper Palaeozoic angular unconformity at the base of the Panjal Trap, along which the whole succession Kurgiakh Formation to Po Formation pinches out NW of Tanze. BAUD et al. (1982a,b, 1984) interpreted this discordance as tectonic (thrust between the "Phuktal" and "Zangla Units"). 1983 BAUD et al. assumed the base of the Zangla Unit at the top of the Panjal Trap; GAETANI et al. (1986, fig. 5) draw the thrust at the base of the Po Formation just above the evaporites of the Lipak Formation. In my view nappes and thrusts do not exist in the whole area. In Zanskar like in other parts of the Tibetan Zone stratigraphic boundaries are frequently disturbed. But, if one follows these disturbances along the strike, in most cases they are shown to be local. There are also some wedges and imbrications, which can be followed over tens of km (e. g. Kangi–Naerung Fault, N. Z. U.-Thrust). Also these shear zones finally end and we find the undisturbed stratigraphic sequences, which contradicts the assumption of nappes.

Returning from these general considerations to the Tanze area, I have shown in the stratigraphical part that the conglomeratic quartzites at the base of the Panjal Trap mark a transgression. The stratigraphic contact of these quartzites to the underlying Po Formation as well as the magmatic contact to the succeeding trap are both undisturbed by tectonics. Naturally the evaporites in the upper portions of the Lipak Formation are disturbed, which is easily explained from the material. Imbrication leads to reduplication of the stratigraphic sequence in the slopes E of Tanze (pl. 2 [15]). Further the thin band of the Muth Quartzite is frequently interrupted by shearing. The rigid quartzites are often squeezed between the Thaple and Lipak Formations. Thus the sedimentary succession is certainly affected by tectonics, particularly where rocks of rather different properties join each other. But the local shearing of stratigraphic boundaries, imbrications etc. do not document the existence of nappes. Several dikes of Panjal Trap in the underlying formations show that these sedimentaries formed the substratum for the volcanic flows, that means that the sequence is stratigraphic and not tectonic.

SE of the village Tanze, in the Surichun La – Phirtse La region, besides folds vertical faults determine the structure. The regional dip is towards the ENE at moderate to medium angles. Deca- to hectometric folds complicate this simple picture (pl. 2 [16, 17]).

Further complication comes from a series of faults (pl. 1, 2) W of the Sinchan camping ground a N–S trending fault crosses the valley leading to Phirtse La. The rocks E of the fault are thrown down. Another fault strikes from SW of Sinchan across the Surichun Valley and the Surichun La to the Chumik Marpo area. Along this NW–SE fault the NE block is subsided. Parallel to the mentioned fault another one crosses Phirtse La recognized already by GAETANI et al. (1985, fig. 1). Again the NE-side is thrown down. The same is shown by a fault crossing the Sinchan Valley near its bend. There the Upper Palaeozoic formations abut against Triassic carbonates. There is also a E–W striking fault NW of Phirtse La and a small NNE–SSW fault at the village Tanze. Generally there is a tendency that the northern and eastern blocks are subsided along these faults. Probably this is related to the uplift of the Great Himalayan Range and the development of the axial depression of Lahoul. Both processes seem to be late orogenic events.

The region between Chumik Marpo and the Yunan Valley shows similar structure. Gently folded the Palaeozoic formations dip beneath the Triassics N of the Lingti Valley (pl. 1, pl. 2 [18–20]). Also in this area there are numerous dikes of Panjal Trap penetrating the underlying series, thus there can be no doubt that the latter represent the original underground, on which the lavas flowed.

A fault crosses the Chumik Marpo Valley in its middle course and may be followed to the lower Kamirup Chu and into the slopes S of the Lingti Chu. Along this lineament the series to the N are subsided.

In the lower Lingti Valley near the Sarchu Plain a peculiar structure is found, which needs more detailed work for its clarification. It seems that the Triassic carbonates are sheared off from their Palaeozoic base along a horizontal (in the W) to NNE-dipping plane (Yunan Valley). The Triassics are in contact with various Palaeozoic formations (pl. 1, 2 [20–22]). I think this structure to be a "faille soustractive" a late orogenic gravity slide like the thrust at the top of the Central Crystalline in the Padam area.

The above shear zone cuts the structures of the underlying Palaeozoics unconformably. S of the Sarchu Plain an anticline crosses the Yunan Valley. This fold is directed SW. Further upstream the sequence Karsha-to Lipak Formation is exposed in both flanks of the Yunan Valley. The series are subhorizontal and appear little disturbed. On the crest W of the valley, however, the Lipak Formation is succeeded by Muth Quartzite and Thaple Formation showing the existence of a huge recumbent fold. Near the Kenlung camping ground it can be observed that the recumbent syncline closes towards the S and therefore is directed NE. BAUD et al. (1984, fig. 7) described the same syncline as SW-vergent. The closure of the syncline at Kenlung proves this interpretation to be wrong. Such NE-directed megafolds along the south-western margin of the Tibetan Zone are not rare. In Nepal a huge NE-vergent recumbent anticline can be followed from the Annapurna- to the Dhaulagiri- and Kanjiroba Group (EGELER et al., 1964; FUCHS, 1967, 1977a; BORDET et al., 1971, 1975).

S of the overturned fold zone of Kenlung most of the country is built by the thick basement series, mainly the Karsha Formation. Younger series, the Thaple Formation and Muth Quartzite, are seen only on the tops of the mountains N of Bara Lacha La. They mark the cores of synclines.

Along the tributary leading from Bara Lacha La to the Bhaga Valley a fault strikes approximately WNW–ESE (pl. 1, 2 [21, 22]). NANDA & SINGH (1976) show the fault already in their fig. 3. S of this fault the rocks are thrown down.

There we find also younger formations up to the Po Formation. The sequence Karsha- to Po Formation is exposed in a wide syncline. Binocular observation suggests that in the mountains S of Bara Lacha La limestones of the Lipak Formation follow on top of the Po Formation. This implies an overturned limb. In my view it is the southern flank overthrown towards the N, which means the existence of another N-directed recumbent syncline (pl. 2 [22]).

The peak W of Pateo is formed by Muth Quartzite marking a small syncline, which may be the continuation of the above dealt syncline E of Pateo.

All the synclines of the Bhaga–Bara Lacha La–Yunan region are ordinary folds of the Karsha to Po succession. There is no reason to assume a thrust (GAETANI et al., 1985, fig. 1). The syncline W of Pateo is shown by these authors as an outlier of the "Phuktal Nappe", thus the younger formations are structurally separated from the underlying Karsha- and Phe rocks ("Phyllites"). E of Pateo, however, the Karsha Formation is included together with the younger formations in the Phuktal Nappe. Actually the Phe ("Phyllite") to Po succession forms a stratigraphic sequence, which was folded but not divided to thrust sheets.

In connection with the tectonics of the Bhaga–Bara Lacha–Yunan area it is necessary to note the varying grade of metamorphism. The Palaeozoic formations of the orographically right slope of the Lingti Valley exhibit phyllitic alteration. I first noticed this metamorphism at the junction of the Karnirup Chu and it seems to increase towards the E. S of the Sarchu Plain I observed dikes of porphyric granite cutting the phyllitic rocks of the Karsha- or Phe Formation. The alteration also affects the younger formations of the Yunan Valley. The red sedimentary colour of the Thaple Formation disappears and changes to greenish or silvery tints (sericitization and chloritization). The carbonates of the Lipak Formation recrystallized to marble. To my surprise the metamorphism fades away towards the S, between Kenlung and Bara Lacha La, and the rock series of the Bara Lacha La–Pateo area are almost free of alteration. S the Bhaga around Darcha a phyllitic metamorphism is recognized again.

In the Tibetan Zone it is a common phenomenon that the grade of alteration increases towards the Great Himalayan Range in the S, and there are frequent passages into the Central Crystalline. Therefore I was surprised about the metamorphism dying away towards the S. The particularities of the geology of the region, however, explain this fact:

1) There is no Central Crystalline to the S of the Tibetan Zone. The latter is connected with the Chamba Synclinorium. The Crystalline plunged beneath this Lahoul axial depression.
2) I expect a granitic intrusive body beneath the sedimentaries of the Yunan Valley. An indication are the granite dikes S of the Sarchu Plain. Further I observed by binoculars that S of Chumik Marpo and in the upper Kamirup Valley swarms of granitic sills and dikes penetrate the country rocks. Thus in the eastern continuation of the Gumboranjan Granite more granitic intrusions are to be expected, and they probably show a similar aureole of contact metamorphism.

4. Conclusions

In Lahoul the Central Crystalline of the Zanskar Range plunges towards the SE and reappears in the Rohtang area and continues SE in the range bordering Spiti to the S. In this axial depression the sedimentaries of the Tibetan Zone are connected with those of the Chamba Synclinorium. Therefore the Central Crystalline crops out only in the western part of the area investigated. In the E exclusively we find the slightly metamorphosed Tethyan series. They are intruded by several granitoids of Lower Palaeozoic (Jaspar Granite) or Alpine (?) age (Gumboranjan Leucogranite). These granitoids may have their magmatic source in the underlying Central Crystalline, but they do not represent this crystalline. As the magmatites show primary contacts with the sedimentaries, they belong to one structural unit. This is in contrast to GAETANI et al. (1985) who assumed tectonic contacts and division in several tectonic subunits.

A major problem is the relation of the sedimentary succession to the Central Crystalline. Recently BAUD et al. (1982a,b, 1984) and BAUD et al. (1985, 1986) proposed the sedimentaries to represent a series of nappes following tectonically on the Central Crystalline. If this was so, the whole of the Tibetan Zone as well as the sedimentary basins of Chamba and Kashmir would be allochthonous in respect to the underlying crystallines. This assumption is contradicted by the fact that in most areas there is a transition between the crystallines and the sedimentaries. In Zanskar also such passages can be observed between Ichar and Purni or in the Zulidoc–Rangdum area. The named authors were misled to their nappe hypothesis, because the primary coherence is disturbed in the area Muni–Padam–Doda Valley. The disturbance, however, is of the nature of an imbrication, probably a gravity slump of the sedimentaries down from the crystallines, when the Great Himalayan Range was uplifted. The limited extent of the tectonic plane – towards the NW and the SE it dies away and the primary transitions are still preserved – shows that it can not be a nappe boundary.

Similarly I am critical to the concept that the Tibetan Zone consisted of a pile of nappes (BAUD et al., 1982b, 1983, 1984; GAETANI et al., 1985, 1986). My doubts come from the experience that the tectonics of the Tibetan Zone are characterized by folding and imbrication with varying vergency, large scale horizontal transport being practically absent. This tectonic style is also typical for Zanskar (pl. 2, FUCHS, 1982b, pl. 2). It can be recognized also in the section given by BAUD et al. (1982b, fig. 4), if we omit their interpretations at depths not accessible to observation. Formation boundaries are sometimes tectonically reactivated – also within the assumed nappes – as stated by BAUD et al. and GAETANI et al. (1985).

Overturned limbs of folds may be sheared, but that does not indicate the existence of nappes. There is virtually no proof of large scale thrusts by windows or outliers.

There are no tectonic repetitions or old series succeeding younger ones. Contrary the whole "pile of nappes" is a sequence of formations corresponding to the stratigraphic succession. This fact is explained by the advocates of nappes as decollement thrust sheets. In my view there is not any indication supporting the assumption of nappes in the Tibetan Zone (the nappes of the Spongtang Klippe are excepted of course – they are units derived from the Indus Zone and are lying on the Tibetan Zone).

The following points suggest the autochthony of the Tibetan Zone:

1) The sedimentaries of the Tibetan Zone are connected with those of Chamba and Kashmir. In all these regions transitions into the underlying crystallines are documented. Passages between frontal parts of different nappes are difficult to explain. Contrary it is easy to explain local disturbances of primarily coherent series.
2) The recumbent folds in the "Phuktal Nappe" showing the SW-direction of the nappe tectonics (BAUD et al., 1984, fig. 7; GAETANI et al., 1985) are actually directed NE (see pl. 2 [21, 22]). They are probably of young age, however can not be cited as reference for thrusting.
3) The proposed nappe boundary between the "Phuktal-" and "Zangla Units" was studied in detail to prove or disprove the tectonic nature.
BAUD et al. (1982a,b, 1984) and GAETANI et al. (1985) assumed the Panjal Trap to form the base of their Zangla Unit. On the spur NNW of Tanze the Po Formation is transgressed by a few meters of conglomeratic quartzite, which in turn is followed by the Panjal Trap with magmatic contact. All the contacts are undisturbed by tectonics. I suppose

that GAETANI et al. (1986) made the same observation and therefore shifted the thrust down to the base of the Po Formation. But also there I did not find indication of a nappe boundary.
Also above the monastery of Phuktal I observed the conglomeratic quartzite, here transgressing on Karsha Formation. Again the quartzite forms the primary base of the flows of Panjal Trap and the contacts are not affected by tectonics. Further W in the Thongde area again the quartzites are found associated with the Panjal Trap. Thus the conglomeratic quartzites and the traps follow as transgressive Permian series on various older formations, showing that the unconformity is stratigraphic and not tectonic.

4) Regarding the same thrust it is significant that numerous dikes of Panjal Trap penetrate the underlying formations. That these mafic dikes really correspond with the Panjal Trap is also strengthened by petrographic examination (GAETANI et al., 1986, 454–45). If the Panjal Trap really would belong to another structural unit (Zangla Unit) the swarms of veins in the formations of the underlying "Phuktal Unit" would be difficult to explain. In my view it is obvious that the Precambrian–Carboniferous formations cut by the Panjal Trap dikes represent the substratum of the volcanic flows and therefore form one original succession.
5) Several folds in the Mesozoic sequence show sheared limbs, which have been interpreted as nappe boundaries (BAUD et al., 1982b, 1983, 1984; GAETANI et al., 1985). The fact that they lose their importance when followed along the strike shows that they are just wedges.
In the southern flank of the Spongtang Synclinorium a thrust was found to separate a northern wedge – the Northern Zanskar Unit (N. Z. U.) – from the rest of the Tibetan Zone (FUCHS, 1982b). This shear zone dies away in the lowest course of the Oma Chu.
Also the northern limb of the Spongtang Synclinorium is sheared. The lineament between the synform and the Honupatta Anticlinorium was called the Kangi-Naerung Fault by KELEMEN & SONNENFELD (1983). It fades away W of Kangi and N of Namtse La, where the normal stratigraphic sequences are preserved.
The Chirche Syncline (BAUD et al., 1982b) seems to be sheared in its NE-limb. In the Shade-Tantak area it is obvious that the Triassic–Jurassic carbonates N of the shear zone belong to the overturned NE limb and not to a next higher nappe ("Khurna Nappe", GAETANI et al. [1985]).
Thus imbricate structures are not rare, but their limited extent contradicts the interpretation as nappe boundaries.

Considering all the arguments there is convincing evidence now that the Precambrian–Lower Eocene succession exposed in Zanskar represents a stratigraphic and not a tectonic sequence. This clarification was necessary before treating questions of the stratigraphic evolution and palaeogeography.

Like in the other regions of the Himalaya the basal Late Precambrian to Early Palaeozoic sedimentary complex is quite distinct from the succeeding formations. It is typical basin facies: The Phe Formation consists of several thousand meters of siltstones, very fine-grained subarkoses, and silty slates. This monotonous sequence frequently shows rhythmic sedimentation. Lamination, graded bedding, ripple cross lamination, flame structures, load convolutions, scour and fills, disturbed bedding, flute casts, groove moulds, linguoid ripples and burrows give a flyschoid character. From the sedimentary features we may infer that there was rich supply in terrigenous material, which was rapidly deposited in a subsiding instable trough. The sedimentation was rhythmic, in part at least controlled by turbidity currents. All this and the large areal extent of these deposits suggets basin sedimentation instead of a tidal flat assumed by BAUD et al. (1984), CASNEDI et al. (1985), and GAETANI et al. (1986).

The Karsha Formation (Middle to Upper Cambrian) indicates filling up of the basin. Algal horizons and reefs are interstratified in the flyschoid series, their frequency and thickness increases upwards.

After this shallow-water episode producing several hundred meters of pelites, siltstones, sandstones, and dolomite, the Kurgiakh Formation was deposited in a renewed flysch environment.

In Zanskar the Cambrian / Ordovician boundary is marked by a break in sedimentary development. The basin deposits are followed by the red conglomerates and sandstones of the Thaple Formation, indicating an alluvial fan to braid-plain environment (GAETANI et al., 1986). This change in sedimentation was brought about by the orogenic event documented in Spiti by an angular unconformity at the base of the Ordovician conglomerates (HAYDEN, 1904; FUCHS, 1982a). The orogeny is further proved by an invasion of granitoids clustering around 500 m. a. (FRANK et al., 1976; MEHTA, 1977; LE FORT et al., 1986, a.o.). In other regions of the Himalaya (Nepal, Kumaun, Kashmir) the sedimentary break occurs later in the Silurian. Considering the sedimentary development of the whole Himalya I proposed a Caledonian orogeny already in 1967. Recently the existence of an Early Palaeozoic orogeny is favoured also by BAUD et al. (1984) and GAETANI et al. (1986) who accept a Late Precambrian–Cambrian Pan African orogeny. LE FORT et al. (1986) stress the fact that very similar 500 m. a. granites have wide distribution also in other fragments of former Gondwanaland, such as Australia and Antarctica. LE FORT et al. point to the importance of the magmatic activity, but consider the associated effects of metamorphism and deformation to be small. The last holds true for the granites in the Chail Units of the Lesser Himalaya, but not for the Central Crystalline where surrounded by migmatites the granites formed during regional metamorphism.

The basin type sedimentation lasted from the Late Precambrian to the Upper Cambrian, regionally to the Silurian and a new aera starts with the Devonian Muth Quartzite. The significant breaks in sedimentation were at the Cambrian/Ordovician boundary (SE-Zanskar, Spiti), after the Ordovician (Nepal, Kashmir). In my view these were phases of the Caledonian aera, which does not imply a connection with the NW-European mountain belt.

The Muth Quartzite (Devonian) indicates stable conditions in an epicontinental environment with strong terrigenous influence. The Lower Carboniferous Lipak Formation was deposited on a shallow carbonate shelf. The gypsum in the upper portions of the formation documents evaporitic environment (sabkha). The Upper Carboniferous Po Formation, an alternation of conglomerates, arenites, and pelites points to an increase of terrigenous detritus, which was rapidly deposited in deltas. Thus the shelf became more unstable, which is also indicated by contemporaneous basaltic volcanism petrographically documented in the Upper Po Formation (GAETANI et al., 1986). This stresses the correlation with the Agglomeratic Slates of Kashmir and Chamba.

The Panjal Trap of the Permian is a marker horizon in the NW-Himalaya. According to HONEGGER et al. (1982), ANDREWS-SPEED & BROOKFIELD (1982), GAETANI et al. (1986) a.o. the Panjal volcanism indicates the rifting related to the opening of the Neotethys. Preceding the volcanism epirogenetic movements caused partial erosion of the Silurian to Upper Carboniferous formations. The thin conglomeratic quartzites at the base of the Panjal flows mark the Permian transgression – the Upper Palaeozoic unconformity.

GAETANI et al. (1986) called the long history of Zanskar from the Permian to the beginning of the Himalayan revolution in the Eocene the passive continental margin stage. The Panjal Volcanics are succeeded by the Kuling Formation of Middle to Upper Permian age. The sequence, shallow-water arenites at the base leading upwards to dark silty shales, reflects the deepening of the invading sea. This tendency is continued in the Triassic. The pelagic limestones and shales of the Tamba Kurkur Formation (Scytho–Anisian) indicate upper bathyal conditions with low rate of sedimentation (GAETANI et al., 1986).

The Daonella Shales and -Limestone, and Grey Beds are all deposits of deeper poorly aerated water with varying carbonate/clay ratio. After the Ladinian beds shallowing and terrigenous influx are indicated by the Carnian Tropites Limestone. The terrigenous detritus supply still increases with the Noric producing the sandy-shaly-calcareous alternation of the Juvavites and Monotis Shales. Traced from the E (Nepal) towards the W (W-Zanskar, Kashmir) the Noric formations show passage from flyschoid series to monotonous limestone-dolomite beds, which I explain by accepting a decrease in water depth.

The Quartzite-Series (Upper Noric – Rhaetic) marks a significant regression traceable throughout the Tethys-Tibetan Zone. The succeeding Kioto Limestone (Rhaetic–Lower Dogger) was deposited on a very shallow carbonate shelf.

Between the Kioto Limestone and the Ferruginous Oolite of Callovian age JADOUL et al. (1985) found a gap of several m. a. The detritus of the shallow-water formation was derived from the craton in the SW. The Upper Jurassic – Lower Neocomian Spiti Shales were deposited in deeper water in an euxinic environment. GAETANI et al. (1986) accept undisturbed mid to outer shelf.

The Upper Neocomian Giumal Sandstone may reach into the Upper Cenomanian according to GAETANI et al. (1986). After long continued carbonate-pelite sedimentation on the Zanskar Shelf this is the first entirely sandy-silty formation. The rich clastic supply in my view was triggered by epirogenetic movements of the Indian Continent. The provenance of the debris is in the SW as shown by the fining towards the NE. The deposition was below the high-energy zone, because of the poor sorting.

With the Middle Cretaceous the facies becomes rather diversified on the Zanškar Shelf. Whereas the clastic sedimentation of the Giumal Sandstone may reach into the Late Cenomanian (GAETANI et al., 1986), the multicoloured pelagic limestones of the Shillakong Formation may commence already in the Upper Albian in other places (BAUD et al., 1982b). This couches rouges facies was deposited on sills or oceanic plateaus. It represents a pelagic well-aerated facies not reached by terrigenous detritus. The Chikkim Limestone may start in the Albian or Cenomanian–Turonian, it is also a pelagic foraminiferal limestone, but deposited in deeper less oxygenated water. Generally the blue Chikkim Limestone facies appears before the Shillakong facies, which replaces it upwards and towards the N. However there are further euxinic silty shales – the Lamayuru facies – interfingering with the pelagic limestones. The beginning as well as the end of the different facies vary from place to place. Generally the Shillakong facies is better developed in the N of Zanskar, where it reaches up into the Upper Campanian (BASSOULLET et al., 1978b). There it is overlapped by the Lamayuru facies in the Maestrichtian, whereas further S this may happen as early as in the Turonian. In SW-Zanskar the Shillakong facies is missing at all and the Chikkim facies (Albian, resp. Cenomanian to Campanian) is directly overlain by the Campanian to Lower Maestrichtian Kangi La Flysch. This formation derived its clastic material also from the SW like the Giumal Sandstone. We may infer that this flysch sedimentation burried the pelagic Chikkim Limestone facies in the SW of Zanskar. In the central and northern parts pelagic sedimentation persisted on ridges and oceanic uplifts. The latter were surrounded by the Lamayuru basin facies, which was in communication with the Kangi La Flysch after the final drowning of the pelagic sills, sea mounts, or plateaus in the Maestrichtian. FUCHS (1982b) took this overlap of the Lamayuru facies as indication that the northern margin of the Indian Continent was already close to the subduction zone. The succeeding Upper Maestrichtian to Upper Paleocene shallow water carbonates probably signal the first touch of the Indian Continent with the Dras Island Arc. After the sedimentation of the Lower Eocene Kong Slates thrust masses slipped from the Indus Suture Zone onto the Zanskar Shelf and folding began.

Regarding the sedimentary evolution I agree very well with the stratigraphic work done by the Italian workers – except in the question of the environment of the Phe Formation and the nomenclature of the Quartzite Series. The major difference is that the Italians deduced the sedimentary history from a sequence, which they thought to be a pile of individual tectonic units, whereas for me it is the original stratigraphic succession. I hope that I was able to demonstrate in the 1982b., 1986 and this paper that the Tibetan Zone of Zanskar is an autochthonous fold belt, primarily connected with the Central Crystalline.

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G. FUCHS – Plate 1

Geological Map of SE-Zanskar

G. FUCHS, 1986

Ausführung: Fachabteilung für Kartographie und Reproduktion, Geologische Bundesanstalt, Wien.
Druck: Freytag-Berndt und Artaria KG, Wien.

Graphik: CH. STEINBAUER

Villages and fields
Talus fans
Large alluvial areas
Mountain slide
Upper Cretaceous in gen.
Black silty slates and marls (Lamayuru Formation; Cenomanian–Maestrichtian)
Shillakong Formation (Albian–Upper Campanian)
Giumal Sandstone (Lower Cretaceous)
Spiti Shales (Upper Jurassic–Lower Neocomian)
Ferruginous Oolite (Upper Dogger)
Triassic–Jurassic Carbonates in gen.
Kioto Limestone (Rhaetic–Lower Dogger)
Quartzite Series (Noric–Rhaetic)
Juvavites- and Monotis Shales (Noric)
Tropites Limestone (Carnic)
Daonella Shales, -Limestone and Grey Beds (Ladinian–Lower Carnic)
Kuling Formation (Permian) and Tamba-Kurkur Formation (Scythian–Lower Ladinian)
Panjal Trap (Permian)
Po Formation (Upper Carboniferous)
Lipak Formation; evaporite facies (Lower Carboniferous)
Muth Quartzite (Devonian)
Thaple Formation (Ordovician–Silurian?)
Kurgiakh Formation (Middle–Upper Cambrian)
Karsha Formation (Cambrian)
Phe Formation (Upper Precambrian–Cambrian)
Increasing metamorphism; granite dikes
Discordant granitoids; dikes and sills
Kado Tokpo granitoids
Central Crystalline in gen.
Dip
(horizontal to vertical)
B-axes
Imbrication
Fault
Anticline, syncline
Position of sections shown in Pl. 2
Scale 1 : 100.000
0 1 2 3 4 5 10 km
G R E A T H I M A L A Y A N R A N G E
Zanskar
Oma Chu
Parfi La
Namtse La 4403m
Pidmu
Zangla 3350m
Zumlung Chu
Zazar
Karsha
3473m
Thongde
Kumi
Thonghe La
Shingri Chu
Doda Chu
Padam
Pipchar
Bardan Gompa
Muni
Reru
Ichar
Tsarap Chu
Abnop
Dolma
Char 3900m
Purni
A
B
1
2
3
4
5
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7
8
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10
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12
13
14

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G. FUCHS – Plate 2

Geological Sections across SE-Zanskar

G. Fuchs, 1986

Ausführung: Fachabteilung für Kartographie und Reproduktion, Geologische Bundesanstalt, Wien.
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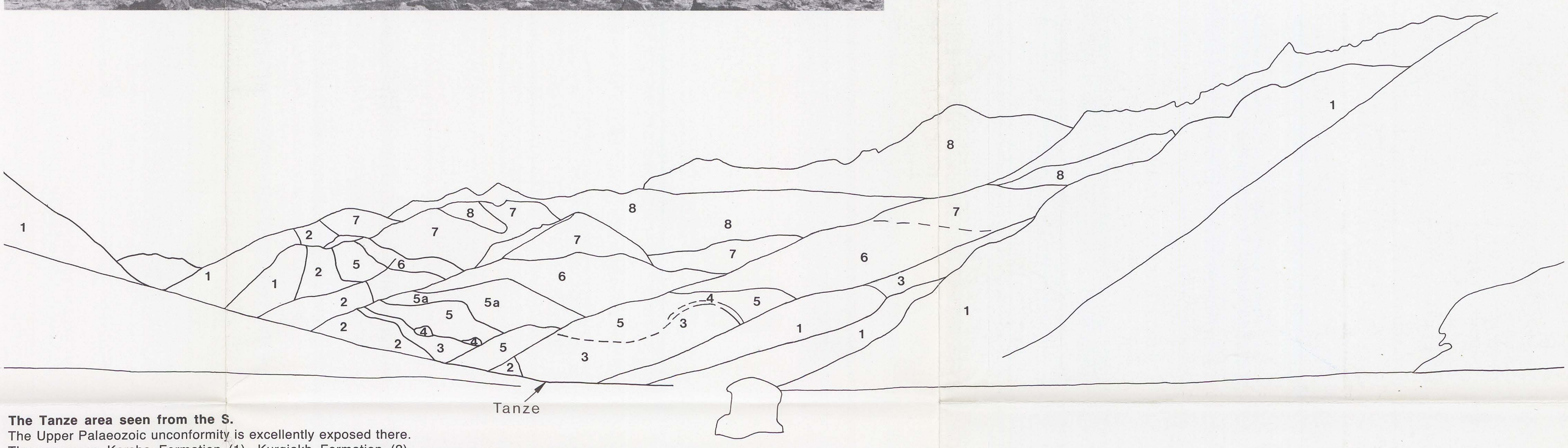
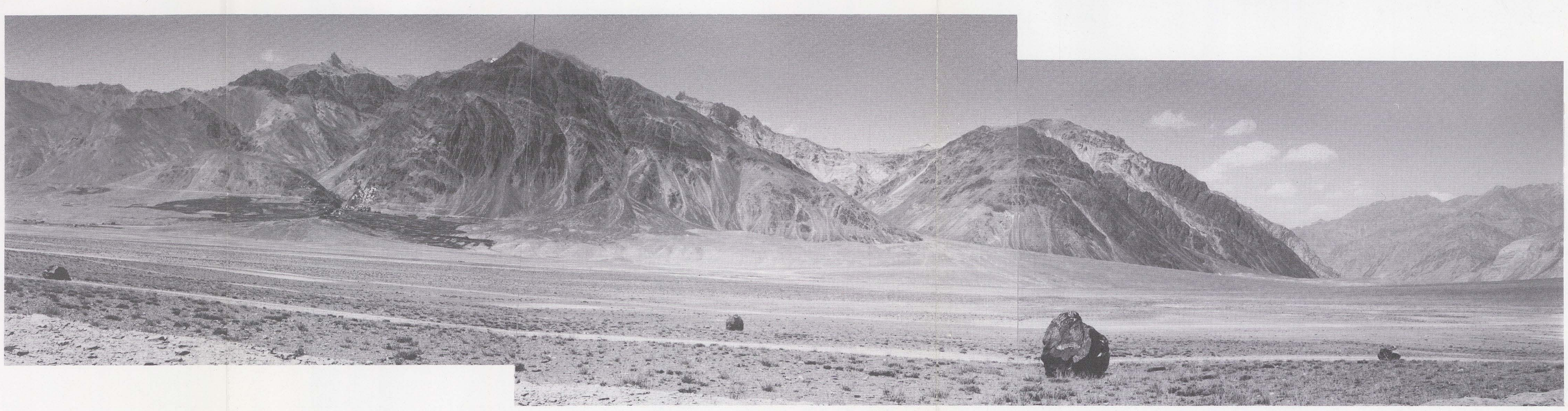
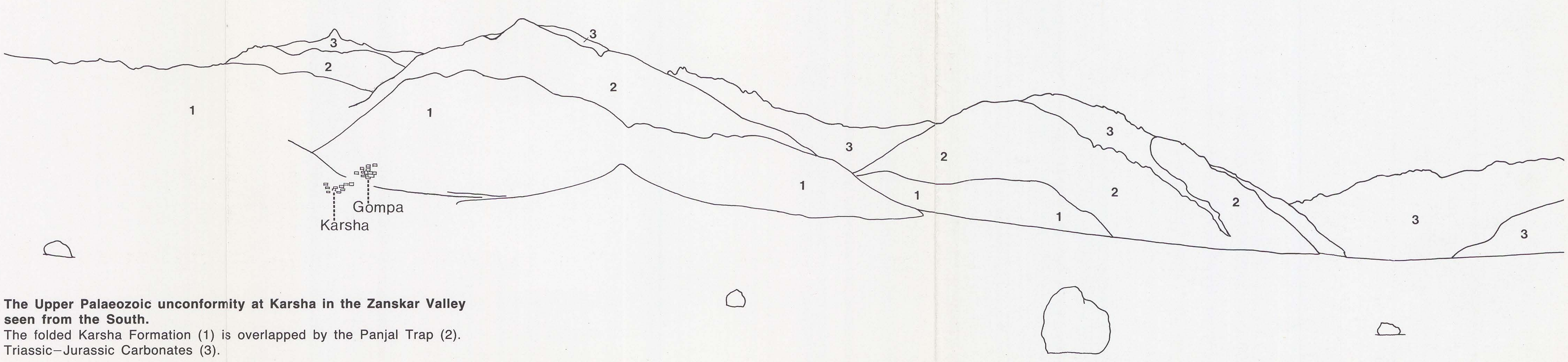


The Tanze area seen from the S.
The Upper Palaeozoic unconformity is excellently exposed there. The sequence Karsha Formation (1), Kurgiakh Formation (2), Thaple Formation (3), Muth Quartzite (4), Lipak Formation (5; evaporites 5a), Po Formation (6) is transgressed by the Panjal Trap (7), Kuling Formation and Triassic formations (8).





The Upper Palaeozoic unconformity at Karsha in the Zanskar Valley seen from the South.
The folded Karsha Formation (1) is overlapped by the Panjal Trap (2). Triassic–Jurassic Carbonates (3).