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The Himalayas seen from Bhutan*)

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With 5 Text-Figures

Bhutan
Himalaya
Stratigraphie
Tektonik
Paläogeographie

Contents

Der Himalaya, gesehen von Bhutan

Zusammenfassung

Die Geologie von Bhutan entspricht der des östlichen Himalayas und ist in mancher Hinsicht verschieden von den mehr westlichen Regionen. Die über 17 km mächtige Kristallindecke ist weiter verbreitet und zeigt eine durchgehende, auffallende umgekehrte Metamorphose, welche nordwärts zunimmt, zusammen mit mächtigen Intrusionen von Leukograniten. Sie nimmt gegen die tibetische Grenze mit der Transgression der Tethys-Sedimente, welche auch in isolierten Becken auf dem Kristallin liegen, deutlich ab. Eine Bruchzone im sedimentären Grenzbereich scheint zu fehlen. Die ältesten Fossilien, nach der Metamorphosenabnahme, deuten ein ordovizisches Alter an. Der Niedere Himalaya bildet eine enge Zone, die sich ostwärts in ein großes, nordwärts streichendes Halbfenster öffnet. Hier ist die Tektonik äußerst kompliziert, mit Schuppen von über 1000 my alten Granitoiden in prekambrischen Sedimenten mit über 5000 m mächtigen Quarziten. Von diesem Halbfenster ostwärts folgt dem Niederen Himalaya eine steilstehende Serie von Kohle-führenden Damudas permo-karbonen Alters, die längs der MBT an eine durchgehende Zone von Siwaliks grenzt, unterbrochen in den westlichen Fußhügeln Bhutans durch eine Überschiebung des Niederen Himalaya. Dies fällt mit einer auffallenden Verflachung des Brahmaputra-Beckens zusammen, mit Shillong-Kristallin nur 35 km südlich der MBT, der engsten Stelle des gesamten Himalaya-Vorlandes.

Sämtliche Bhutan-Elemente lassen sich durch den östlichen Himalaya bis zur Osthimalaya-„Syntaxis“ verfolgen. Die enge Damuda-Zone erweitert sich längs des Siang-Flusses (dem N–S-laufenden Brahmaputra) mit den auftretenden Permischen Abor-Vulkaniten, welche den West-Himalaya Panjal Trapps entsprechen, beide Vulkanite beschränkt auf den West- und Osthimalaya. Die Abor-Vulkanite bilden eine komplizierte Antiform, mit einem Fenster von marinem Eozän in der Siangschlucht. Die Antiform entspricht in ihrer Größe der Hazara-Kashmir-„Syntaxis“ im Westen. Das Äquivalent des Nanga-Parbat-Hochs im östlichen Himalaya könnte die Namche Barwa Kulmination sein. Die Verbindung mit der Abor-Struktur ist noch unsicher.

Der Himalaya endet nicht mit den entsprechenden Syntaxen sondern mit auffallenden Bruch- und Überschiebungszonen, der Sarobi- und Chaman-Bruchzone im Westen und der Mishmi-Decke im Osten. Der Westen ist bekannt durch ausgedehnte Evaporitzonen, aufgeschlossen in der Salt range, welche wichtige Abscherungshorizonte bilden. Sie sind verantwortlich für die Diskrepanzen zwischen Oberflächen- und Tiefenstrukturen. Evaporite sind bis jetzt im Osthimalaya unbekannt, abgesehen von spät-präkambrisch–kambrischen Gipshorizonten im südöstlichen Bhutan – Niederer Himalaya. Eine 6000 m mächtige eozäne Flyschzone, mit Übergang in Molasse, folgt über den allochthonen Quetta- und Las Bela-Ophioliten, welche auf den Westrand des Indischen Schildes aufgeschoben sind. Eine ähnliche Flyschzone, hier mit exotischen Blöcken, folgt den allochthonen Naga-Ophioliten der Indo-Burmesischen Ketten. Sie sind auf das Shillong- und Mikir-Kristallin des östlichen Indischen Schildes aufgeschoben. Eine ähnliche Flyschentwicklung ist aus dem Haupthimalaya nicht bekannt.

Die hervorragende, südost-streichende Mishmi-Überschiebung, die sogar quartäre Sedimente überdeckt, schneidet sämtliche Haupteinheiten des Himalaya sowie die Indo-Burmesischen Ketten ab. Der komplette Tethys-Himalaya ist zwischen einer dünnen Kristallinlamelle und den noch enigmatischen Tidding-Ophioliten verschwunden, welche sich in den Westrand des Burmesischen Shan Plateau verfolgen lassen. Die Tidding-Zone ist südwestwärts von Graniten überschoben, die an den Trans-Himalaya erinnern.

Es ist besonders auffallend, wie der östliche Himalaya, die Mishmizone und die Indo-Burmesischen Ketten über hunderte von Kilometern von Norden, Nordosten und Südosten dem Shillong-Schild und seiner östlichen Fortsetzung, dem Assambecken, mit mehreren tausend Metern von neogenen und quartären Sedimenten aufgeschoben sind. Trotz der rezenten Seismizität mit N–S-Bewegungen im Grundgebirge scheint sich diese östliche Fortsetzung des Indischen Schildes, relativ zu den Überschiebungen nicht bewegt zu haben.

*) Lecture given to the 8th Himalaya Karakorum Tibet Workshop which took place in Vienna from March 29th until April 4th.
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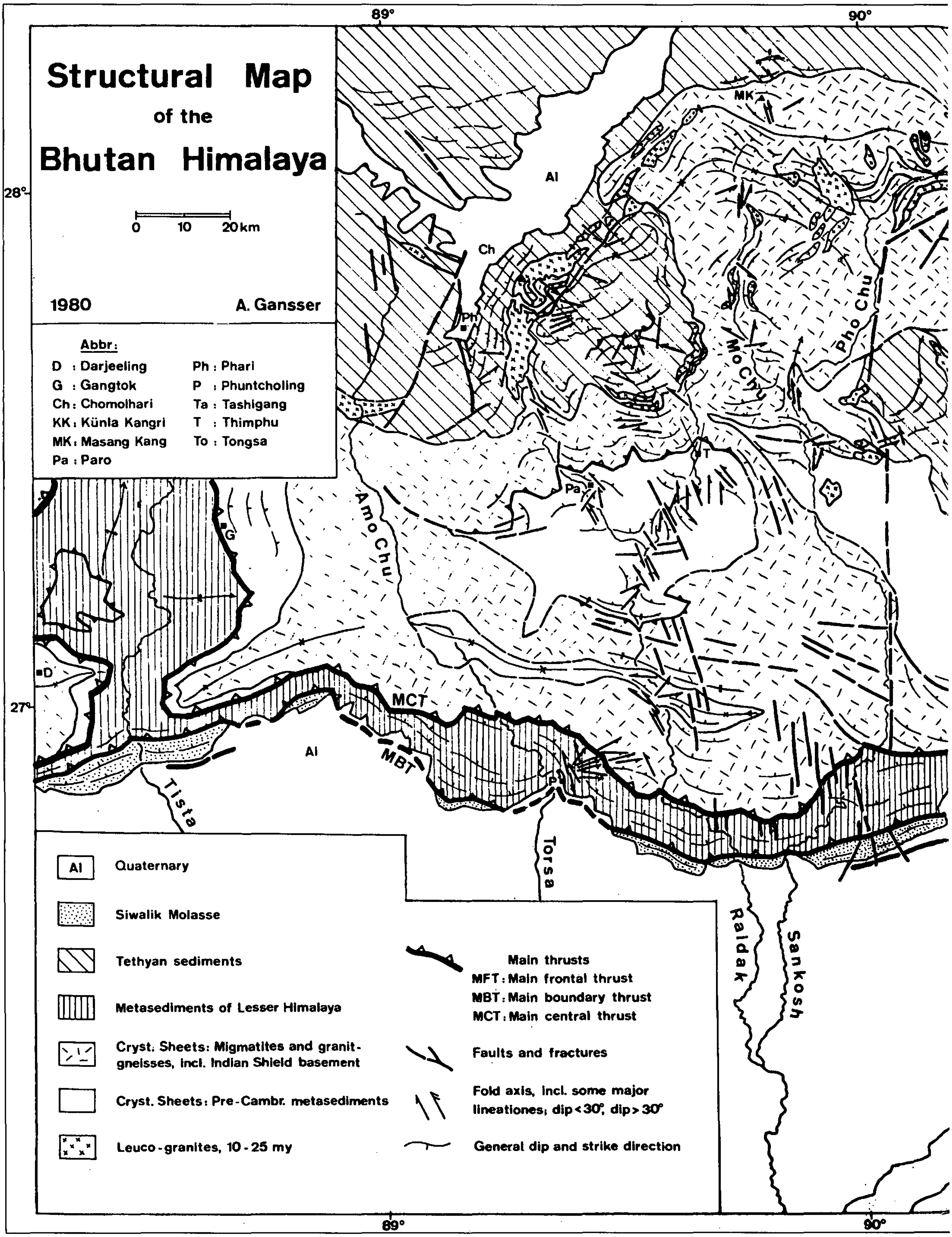

Text-Fig. 1.
Structural map of the Bhutan Himalaya.
Note the large Kuru Chu Spur on the east and the strong neotectonic overprint with NS-directed fracture and fault zones.

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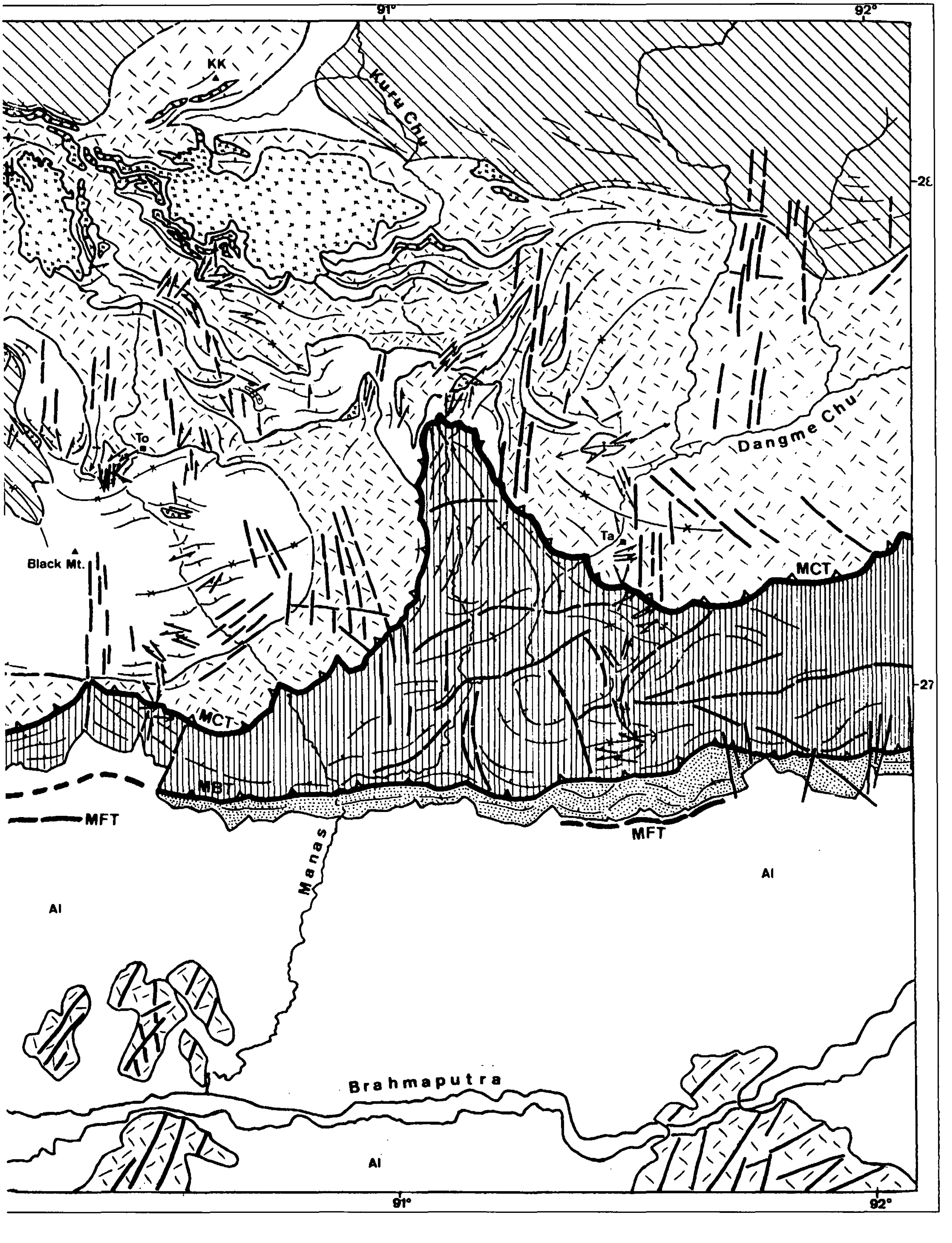

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Abstract

The geology of Bhutan represents the eastern Himalayas and differs in many aspects from the more western regions. The over 17 km thick central crystalline thrustsheet is more widespread and exposes throughout a remarkable reversed metamorphism, increasing northwards with large intrusions of leucogranites. It decreases suddenly towards the Tibetan border with the transgressive Tethyan sediments which also occur in some isolated basins on top of the crystallines. No Tethyan fault zone exists in the north and the earliest fossils, after decreasing metamorphism, suggest an Ordovician age. The Lesser Himalaya forms a narrow band but opens eastwards into a large, northwards directed spur with complicated internal tectonics, emphasized by slices of over 1000 my old granitoids in late Precambrian sediments, dominated by 5000 m thick quartzites. From this spur all along the eastern Lesser Himalayas outcrops a steep narrow band of Permo-Carboniferous, coal bearing Damudas, bordering along the MBT the constant belt of Siwaliks, interrupted only along the western Bhutan foothills, overthrust by the Lesser Himalaya. This coincides with a remarkable shallowing of the Brahmaputra basin with Shillong elements outcropping only 35 km to the south of the MBT, the narrowest spot of the whole Himalayan foreland.

All the elements from Bhutan can be followed through the eastern Himalayas until the East Himalayan "syntaxis". The narrow Damuda belt opens along the Siang river (N–S directed Brahmaputra), with the incoming Permian Abor volcanics, the equivalent of the West Himalayan Panjal traps, both volcanics restricted to the west and east end of the Himalayas. The Abor volcanics form a complicated north plunging antiform with a window of marine Eocene in the Siang gorge, its size similar to the Hazara-Kashmir "syntaxis" in the west. The equivalent of the Nanga Parbat uplift in the east Himalayas could be the Namche Barwa high, though the structural connections with the Abor spur are still vague. The Himalayas do not end with the respective syntaxis but with remarkable fault and thrust zones, the Sarobi and Chaman faults in the west, the Mishmi thrust in the east.

The west is characterised by widespread evaporites, outcropping in the salt range, forming an important decollement horizon. They are responsible for the discrepancies between surface and subsurface structures. Evaporites are so far unknown in the eastern Himalayas except for some late Precambrian–Cambrian gypsum horizons in the Shumar spur of the Lesser Himalaya in southeast Bhutan. A 6000 m thick Eocene flysch belt grading onto a younger molasse follows the allochthonous Quetta and Las Bela ophiolites, thrust on the west border of the Indian shield.

A similar flysch zone, here with exotic blocks, is related to the allochthonous Naga ophiolites of the Indo-Burman ranges. They are thrust towards the Shillong and Mikir massifs of the eastern Indian shield. No similar flysch development is known from the main Himalayan range. The outstanding, southeast striking Mishmi thrust which overrides even Quaternary sediments, cuts all the main Himalayan elements as well as all the Indo-Burman ranges. The complete Tethyan Himalaya has disappeared between a thin crystalline belt and the still enigmatic Tidding ophiolite zone, which continues into the western border of the Burmese Shan plateau. The Tidding zone is southwestwards overthrust by granites reminiscent of the Transhimalaya.

It is most conspicuous how the eastern Himalayas, the Mishmi hills as well as the Indo-Burman ranges encroached for hundreds of kilometers from the north, the northeast and the southeast on the Shillong shield and its northeastern continuation under the Assam basin, with several thousand meters of Neogene and Quaternary sediments. In spite of recent seismicity, trending north–south in the middle of the basement, this northeastern continuation of the Indian shield has remained fixed.

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Most of the published research-work, the themata discussed on workshops and international congresses on the wider Himalayas deal with the western and central part of the range. This for the easier access, better exposure, climate and less political restrictions. These conditions change drastically from Sikkim to the east, with difficult field-conditions, more intense monsoon with over 10 m of rain in Assam, restrictions for foreign investigators and border disputes. The latest Chinese maps still show their borders along the Assam foothills and not at the Mac Mahon line, an area which the Chinese invaded and retreated from in 1962.

These eastern Himalayas are the domain of the geologists of the Geological Survey of India, their excellent work only partly published and without regional maps. My own experiences in these areas are based on a visit to Sikkim and expeditions into the Bhutan Himalayas from 1963 – the year after the Chinese invasion of the eastern areas – until 1977 (GANSSER, 1983).

The geology of Bhutan represents the eastern Himalayas and in many aspects it differs from the well known western regions (LE FORT, 1989). The main subdivisions remain, but of particular interest are the contacts and the internal structures (Text-Fig. 1). The foreland of the Bhutan Himalayas is dominated by the Shillong section of the Indian shield. Only 35 km separate the foothills from a crystalline spur, the narrowest spot in the whole Himalayan foreland. To the north of this spur as well as westwards towards Sikkim, the otherwise very constant belt of Siwaliks is interrupted and over this probably erosive gap the elements of the MBT are thrust southwards or are covered, together with the Siwaliks, by quaternary terraces, overprinted by conspicuous neo-tectonics. Similar to the Sikkim foothills, the MBT separates the Siwaliks from a belt of fossiliferous, coalbearing Permo-Carboniferous Damudas, well exposed along the eastern foothills from where this narrow but very constant belt continues to the very east end of the Himalayas. North of the Damuda belt, the Lesser Himalayas, again with a thrust contact, are highly complicated, narrow along western Bhutan. They open eastwards into a large, northwards directed spur, in size similar to the well known spur of Sikkim. Drained by the Kuru Chu, with its headwaters in Tibet, this Kuru Chu spur exposes a most complex, independent, internal tectonics. Unique in this area is the involvement of basement type granite gneisses as various thrust sheets with mylonitic contacts (RAY et al., 1989). They occur in the Lesser Himalayas Late Precambrian Daling section with phyllites, quartzites and dolomites which I called Shumar group. The crystallines are far below the MCT and have nothing to do with crystalline wedges of the High Himalayas. They are unlike the widespread, famous 500 my cordierite granites of the Lesser Himalayas in the west. A tentative age gave 1010 my. They could represent one of the rare occurrences of basement below the Lesser Himalayan sediments. Similar mylonitic granite gneisses have been described in detail from the eastern Daling phyllites in the Sikkim spur as Lingtse gneisses (ROY, 1980) and compared to tectonically emplaced basement slices.

Dominant in the Shumar sediments are quartzites, up to 5000 m thick. Arkoses are missing and the origin of this large mass of quartzites remains an open question. They are wide-spread in the Lesser Himalayas further to the east, described as Miri quartzites in the Kameng, Subandsiri and Siang districts (TANDON et al., 1980). In the Siang region some Skolithos-like pipes have been observed.

The Main Crystalline of the Bhutan Himalayas extends for over 150 km from S to N, from the MCT to the Tethyan transgression, one of the largest Main Crystalline masses of the Himalayas. In the S, the MCT is sharp, with-

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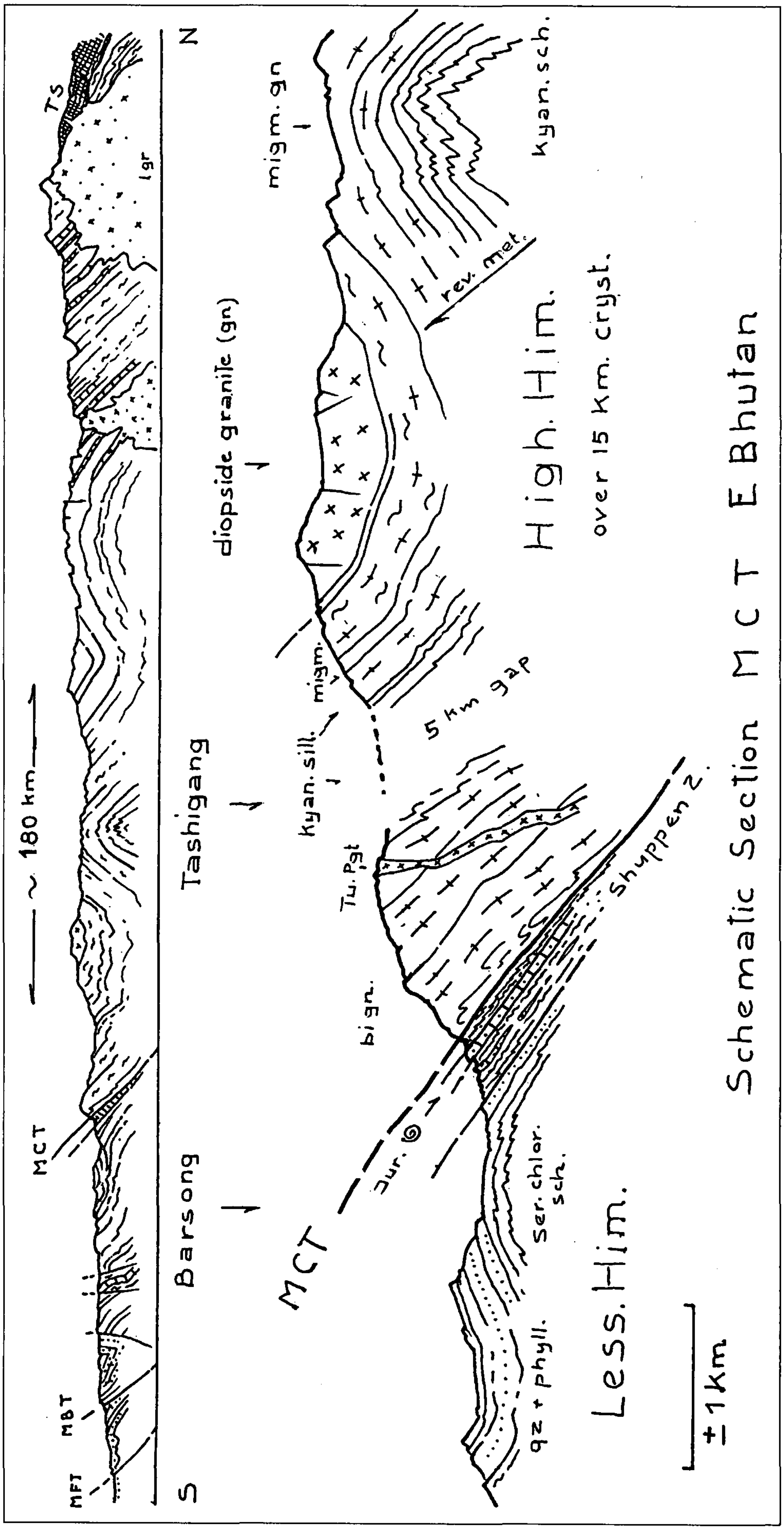
out the otherwise frequent zones of imbrications. This situation changes along the northern plunge of the Kuru Chu spur where the MCT is structurally more complex and less well defined. This rather rapid changing of the MCT outline seems related to the erosional front of the Main Crystalline, which in Bhutan seems sharper in the south and more complex towards the north, which suggests that this large thrust mass deformed penetratively during its displacement (PRICE, 1988). Locally the sharp MCT contact in the south is accentuated by a surprising wedge of Jurassic sediments with preserved palynomorphs (PANTIC et al., 1981) along the eastern Kuru Chu spur, challenges most theories related to the well known reversed metamorphism. Below this wedge follow 5000 m of the late Precambrian Shumar group of the Lesser Himalayas and above, after some meters of phyllonites, the gneisses of the Main Crystalline (Text-Fig. 2).

This very sharp Main Central Thrust (MCT) actually divides two conspicuously different elements, the Lesser Himalayas below from the Higher Himalayas above. Nowhere in the whole Himalayas are the related structural and lithological differences



Text-Fig. 2.
The sharp MCT with an imbricated wedge of Jurassic on the east side of the Kuru Chu spur.
The upper, general section shows the strong folding of the Main Crystalline with a reversed metamorphism. Leucogranites and calcsilicates in the northern end with the Tethyan transgression (TS).

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so pronounced as in the Bhutan section and the following eastern Himalayas.

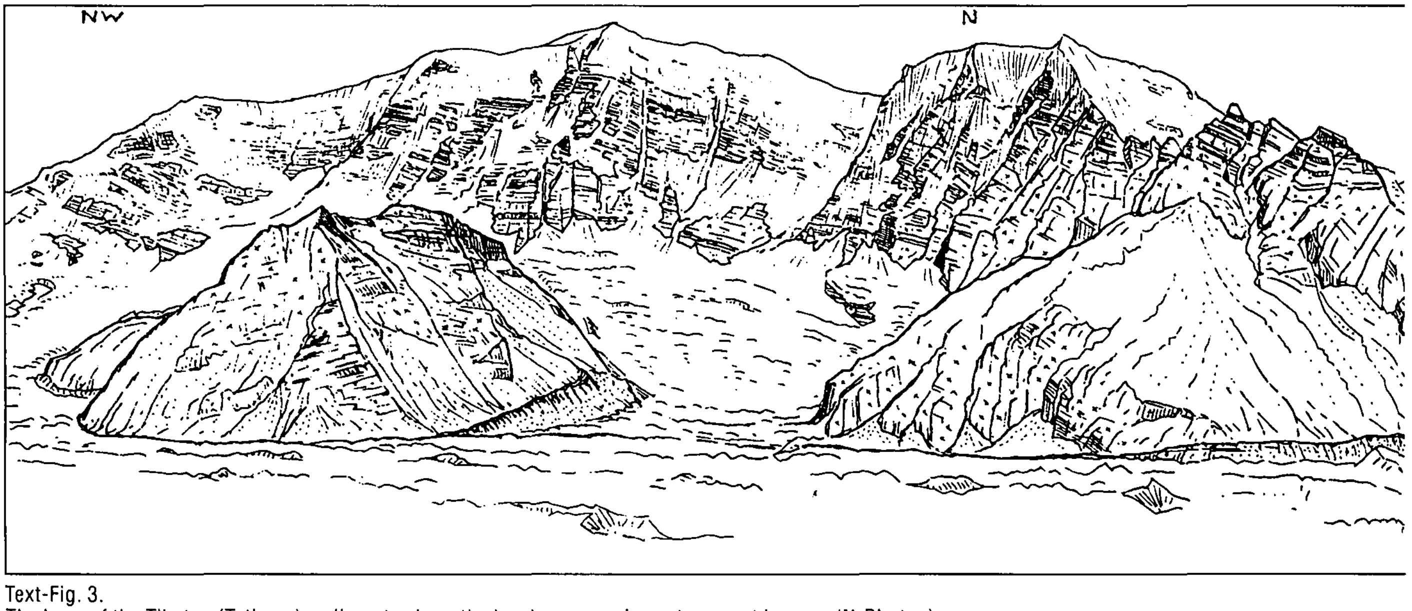
This striking difference between the Lesser and Higher Himalayas must have been inherited from the northern Indian Shield with the highly differentiated Pre- and Post-Aravalli elements (ROY, 1988; SINHA ROY et al., 1993). It is along the contact of these structurally and lithologically different shield sections that during the Post collisional phase of the Himalayan orogeny the MCT developed.

A well outlined reversed metamorphism is most characteristic for the whole Bhutan High Himalayas except near the overlying younger basins and the northern contacts with the Tethyan sediments. The Main Crystalline rock type are the sillimanite-garnet-biotite Takhtsang gneisses named after the famous rock monastery where the characteristic eye-shaped calcsilicate lenses were taken for hand and foot prints of the founder of many of the Bhutanese holy sites Padmasambhava. The Takhtsan gneisses resemble the high grade gneisses of the Darjeeling region with the same concretions. In the Darjeeling region they have been regarded as anatectic "restites" which need extremely high temperatures to melt (GHOSE, 1980). Actually there are all gradations from the original Takhtsang gneisses to migmatitic types with most of the original mineral content preserved. Migmatites with local granitisations are particularly frequent in the northern regions, well exposed in the dominant Masang Kang mountain. Here, within the migmatitic gneisses occur fully mobilized biotite granites with large orthoclases and cordierite crystals. These mobilized granites begin to intrude discordantly into the migmatites. A preliminary whole rock age gave approximately 400 my. The age and the cordierites recall the well known 500 my old, anorogenic granites of the western Himalayas (LE FORT et al., 1980).

Within the Main Crystalline one notes various zones of high grade metasediments, conspicuous by carbonate layers (Paro type) which in the northern region form repetitious bands of high grade calc-silicates, most of them normally interbedded within the gneisses. In these northern zones dominate the leucogranites, particularly well exposed in the Bhutan Himalaya with one of the largest known pluton in the northeast, cutting discordantly the calc-silicate bands while sill-like bands of leucogranite frequently alternate with the calc-silicates in the marginal parts of the larger bodies. The relation of calc-silicates and leucogranite sills is particularly well exposed in the south faces of the Chomolhari range. The leucogranites are genetically unrelated to the much older migmatites which they discordantly intrude.

The high grade metamorphism of the Main Crystalline decreases rapidly towards the Tibetan border with the transgressive Tethyan sediments which also occur in some isolated basis on top of the crystallines such as the Lingshi basin, up to Cretaceous and the more centrally situated Tang Chu basin with a Devonian fauna. The main Tethyan sediments of the north border of Bhutan are derived by a conspicuous crystalline spur of the 7600 m Künla Kangri, the highest mountain in the eastern Himalayas apart form Namche Barwa at its east end. This spur divides the well differentiated sediments of the wider Kampa Dzong basin in the W from the several thousand meters thick black slates and shales of the Kuru Chu headwaters in the E. Here they are cut by frequent N–S-directed fracture and fault zones together with hot springs, good examples of neo-tectonic overprints (GANSSER, 1991).

Of special interest is the transgressive contact of the Tethyan sediments on the Main Crystallines, differring from the more western regions. In the Masang Kang area an irregular surface of gneisses, migmatites and granites is covered by calcschist which contains a wild mixture of calc-silicate fragments and larger minerals, suggesting reworked calc-silicate layers. Conformably follow marble bands, quartzites, micaceous graywacke with a marked vertical cleavage, well bedded sandy marbles with cross-biotites, black slates, spatic limestones with recrystallized fossil remnants (crinoidal, algal remnants, brachiopods) which suggest a doubtful Lower Paleozoic age. The same sediments can be followed to the watershed of the Toma La at the Tibetan border where already unmetamorph dolomites and limestones contain a Silurian to Devonian fauna. Further eastwards toward the upper Lunana, the contact zone is visible in highly glaciated border ranges. Here the gneisses are covered by gently northwards dipping thick lime, silicate and marble



Text-Fig. 3.
The base of the Tibetan (Tethyan) sediments along the border ranges in easternmost Lunana (N-Bhutan).
The top is formed by well-bedded marbles and calcschists sitting on migmatites with calc-silicate bands (Pre-Cambrian), profusely intruded by leucogranites, often sill-like (from GANSSER, 1983).

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bands alternating with sill-like leucogranite intrusions, reminiscent of the south faces of Chomolhari. They form the base of the sedimentary section (Text-Fig. 3).

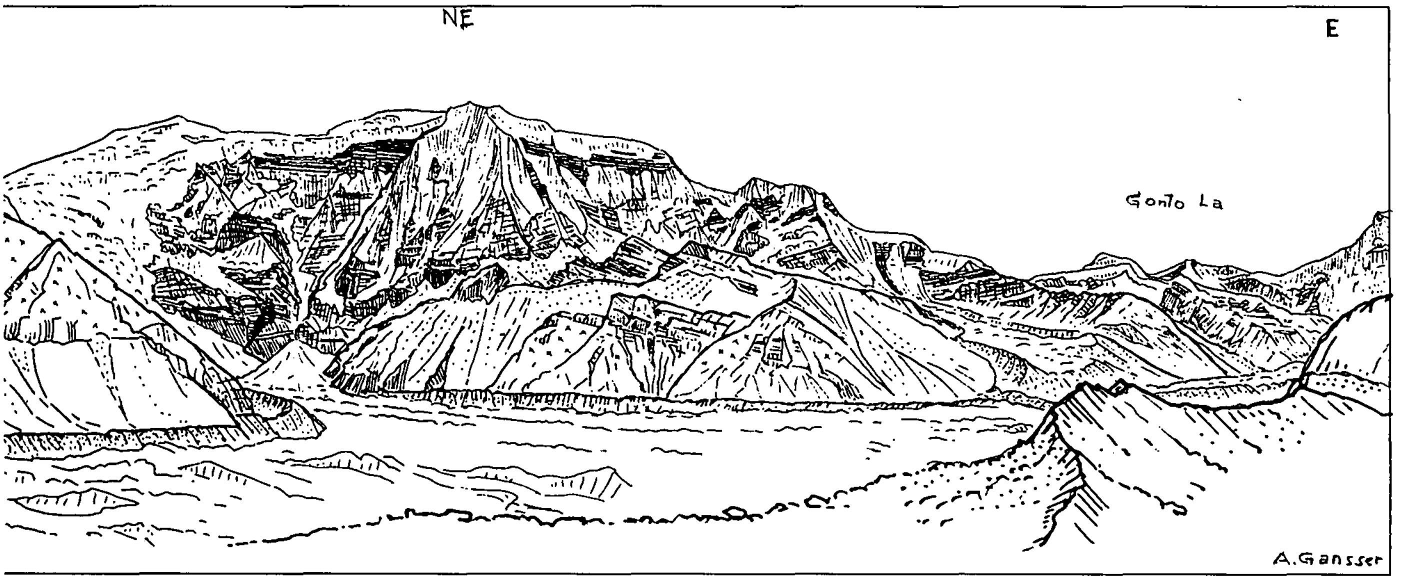
Comparing our contacts with Tethyan sediments in the Central Himalayas we note that several thousand meters of Late Precambrian argillaceous facies, the Martoli/Garbang formations of the Kumaon, or the thick calcareous equivalent of the Anapurna in Central Nepal, are missing. From these facts we may conclude that a very early consolidated section of the Indian Shield, the later Bhutan Main Crystalline, was uplifted and eroded prior to the Lower Paleozoic transgression. Most of the widespread migmatites are most likely pre 400 my and possibly formed in late Pre-Cambrian. The frequently intercalated calc-silicates may belong to a metamorphic phase prior to the Lower Paleozoic transgression since they were observed in a basal breccia in the eroded granites. Except for the Leucogranite phase, present in the whole Himalayas, in the Bhutan Himalayas, and, as far as known in the wider eastern Himalayas, the Main Crystalline slab was much cooler than in the western Himalayas where locally a high grade metamorphic front reaches even the Lower Jurassic, well developed in the Suru river area, of the western Zanskar ranges (HONEGGER, 1983; KÜNDIG, 1988).

In spite of this old, high temperature consolidation of the Bhutan crystalline we cannot neglect strong Himalayan structural overprints exposed in the many internal thrusts and faultzones, dominated by the MCT and the subsequent strong folding and warping of the many kilometers thick crystalline sheet resulting in the dominant spurs of Kuru Chu and Sikkim. Syn- and mainly postgenetic with the last of these structural phases we have the intrusions of the leucogranites, locally with a strong contact metamorphism but unrelated to the much older regional metamorphism. They initiate in the whole Himalayas the morphogenic phase of uplift (SORKHABI & SLUMP, 1993).

All these elements from Bhutan can be followed through the eastern Himalayas until the East-Himalayan "Syntaxis". The Lesser Himalayas form a rather wide belt and the satellite pictures show a pronounced NE strike, cut by numerous, nearly E-W-directed faultzones between Bhutan and the Subandsiri river. They seem to cut also the here badly outlined MCT. The Miri quartzites, partly well bedded, seem widespread. The very constant but narrow Permo-Carboniferous Damuda belt is highly sheared and tectonic slices of marine Eocene sediments occur along the MBT (Geol. Surv. India, 1986). This narrow Damuda belt opens eastwards along the Siang river, the N–S-running upper Brahmaputra, into a large north directed spur.

At the same time the Permo-Carboniferous volcanics increase, culminating in the large extensions of the Abor volcanics with fossiliferous intertrappean beds, comparable to the Panjal Traps of the western Himalayas (PRASAD et al., 1989). They form a complicated antiform, plunging to the north with a window of marine Eocene in the Siang river gorge and overthrust by the older Lesser Himalayan formations (ARCHARYYA, 1992). In size this structure is similar to the Hazara/Kashmir syntaxis in the west. The continuation into an equivalent of the Nanga Parbat crystalline uplift could be the still little known Namche Barwa uplift, with its 7800 m the highest mountain of the E Himalayas while Nanga Parbat is the highest peak of the West Himalayas. From the Abor north plunge, crystalline rocks continue along the Siang (Brahmaputra) with a sharp NE strike (satellite photos) and are cut at the complicated bend of the Siang, here Yarlung Tsangpo, by sharp, eastsoutheast striking faultzones rich in hot springs and most likely connected to the Nienchen Tangla trend of the Lhasa "plate". The same NE strike direction is again visible southwest of Namche Barwa (satellite photos), a trend which connects with the Indo Yrlung Suture. From these so far conjectural observations, the overall structural picture is again not unlike the north end of the Nanga Parbat uplift.

The Himalayas do not end with the respective "syntaxis" but with remarkable fault and thrust zones. In the west we note the Sarobi and Chaman faults, in the East the Mishmi thrust. Still both ends are conspicuously different. From the Hazara syntaxis the westernmost Himalayas continue for about 500 km with a foreland rich in Late Precambrian/Cambrian evaporites, outcropping in the Salt Range. They are responsible for the discrepancies be-



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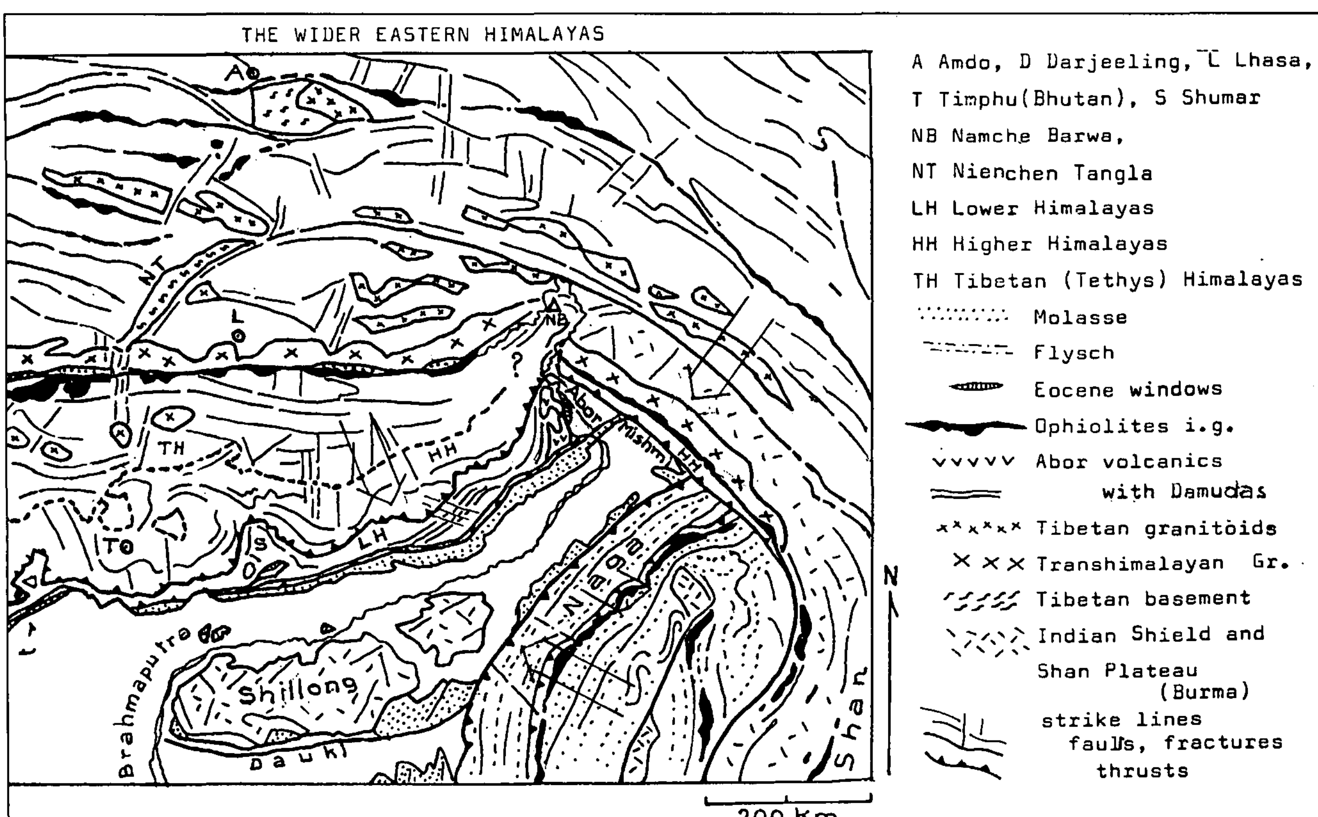
tween surface and subsurface structures (SEEBER & ARMBRUSTER, 1979). Evaporites are so far unknown in the eastern Himalayas except for some late Precambrian gypsum horizons in the Shumar group of the Bhutan Lesser Himalaya (JANGPANGI, 1974). From the Abor syntaxis to the E not much is left of the Himalayas, cut out by the dominating Mishmi thrust. Below this outstanding thrust, which overrides even Quaternary terraces, all the main Himalayan elements have disappeared, such as the Siwaliks, the Lesser Himalaya and the complete Tethyan Himalayas. Only a small belt of High Himalayan Crystalline is preserved below a strongly sheared layer of ophiolites, the controversial Tidding Suture which is overthrust by tonalites reminiscent of the Transhimalaya plutons. The Tidding suture could be projected into the steep thrustzone SE of Namche Barwa and thereby come close to the eastern end of the Indo-Yarlung suture (Geol. Surv. India, 1986). Southeastwards the Mishmi thrust cuts all the Indo-Burman ranges, and, together with the Tidding ophiolites merges into the western thrust-border of the Shan basement crystalline (BENDER, 1983; BRUNNSCHWEILER, 1974, 1983).

To the SE of the Assam basin and dominating the Indo-Burman arc ist the allochthonous Naga-Chin Hills ophiolitic belt which is thrust over a Lower Tertiary flysch, which grades into a more molasse type facies (Disang formation). This again is thrust on an outer molasse belt of the Assam basin, an equivalent of the Siwaliks, with sharp folds and local thrusts, decreasing basinwards (Text-Fig. 4).

The strongly dismembered Naga ophiolites contain intercalations of Maestrichtian beds and are transgressed by the Eocene Phokphur formation with ophiolite derived volcanoclastics. It resembles somewhat the Shigatse "flysch" (BURG, 1983) of Albian–Cenomanian age transgressing the Indo-Yarlung ophiolites. It stresses the age difference between these and the Naga ophiolites. Some klippen of basement, derived from the E, cover some sections of the ophiolites, a fact unknown from the older Indo Ayrlung suture (ACHARYYA et al., 1989). Apart from the widespread mafic volcanics occur metabasaltic rocks with eclogites and glaukophane schists. The geochemical evidences suggest two contrasting rock suites with a different origin (VENKATARAMANA & DATTA, 1987).

Comparable to the Naga ophiolites which represent the Peri-Indian suture zone on the E side of the Indian plate (SENGUPTA et al., 1990) are the ophiolites of the Quetta-Las Bela belt which are thrust towards the west edge of the Indian Shield (GANSSER, 1979). They contain blocks of Maestrichtian age in the basal melanges and are transgressed by Lower to Middle Eocene limestones which grade into large flysch belts (ALLEMANN, 1979). Age and associated flysch belts, changing into molasse, are similar to the Naga ophiolites. Even klippen of crystalline, consisting of a 2 km large mixture of white marbles with chlorite and biotite schists sitting on doleritic diabase in the northern Las Bela belt, resemble strikingly the crystalline klippen on the Naga ophiolites (GANSSER, 1979).

The eastern Himalayas, the Mishmi hills and the Naga ranges are thrust for hundreds of kilometers towards the Assam basin, covering the NE spur of the Indian shield which outcrops in the Shillong and Mikir basement uplifts. These uplifts are separated from the main Indian Shield by the northern N–S-trending Bengal graben. On its west border the Shillong massif is cut by the N–S-trending Dhubri fault. The complexity of the graben is well displayed on the eastern edge of the Main Shield with the N–S-striking belt of Rajmashal volcanics which have now been dated



Text-Fig. 4.
The eastern "Syntaxis" of the Himalayas with large overthrusts on top of the Shillong part of the Indian Shield.

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with 100 my, somewhat older than the Deccan Traps (67 my). They are related to the Gondwana trough, exposed along the eastern shield margin. Seismic and drilling data indicate that the coal-bearing Carboniferous to Lower Cretaceous Gondwanas, following a N–S fault-controlled trough, continue below the surface in both directions and reappear in the N in the Rangit valley tectonic window in the Darjeeling Himalayas (MUKHOPADHYAY et al., 1989). This is thus one of the examples how Bengal graben tectonics reappear in the rejuvenated N-S-directed fault and fracture patterns of the Himalayas (DASGUPTA et al., 1987). In spite of the large Bengal graben the easternmost shield elements, Shillong and Mikir of the Assam basin have remained well welded to the Indian plate as its northeastern spur. The transcurrent eastwards movements of 250 km along the Dauki fault on the south side of the Shillong massif (EVANS, 1964), have not been verified (BRUNNSCHWEILER, 1983). On the other hand the Shillong massif seems seismically surprisingly active, with an apparent N–S trend (VERMA & KRISHNA, 1987; MOLNAR, 1987).

In conclusion it may be tempting to compare the northwestern with the northeastern end of the Indian shield or plate and their relation to the respective Himalayan "syntaxis" (Text-Fig. 5). The western spur is very wide with the outcropping small shield elements of the Kirana hills. Dominant is the evaporite facies of the Saltrange which, by drilling, has been traced nearly to Delhi and which strongly influences the structural style. The western (Kashmir) Himalayas are thrust from the NE with a particularly wide belt of Siwaliks. The Salt range is thrust from the NW, only 60 km away from the Kikrana shield-elements. The wide, eastwards bulging structures of the Suleiman range are thrust to the E. The overall encroachment of the border ranges on to the northwestern spur of the Indian plate is, however, considerably smaller compared to the very narrow northeastern spur of the Assam basin. For hundreds of kilometers the respective border ranges have overthrust the narrow northeastern spur of the Indian plate, which at present seems to become more narrow and shallower at its E end (DAS, 1992).

The East-Himalayan geology corroborates the great mobility of the border ranges dominated by large overthrusts on an apparently stable and fixed Indian plate. How far can this "scenario" be applied for the whole Himalayas? We must realize that India has influenced its frame, including Eurasia, from the Precambrian orogenic phases of the Aravallis onwards and I strongly feel with JOHN AUDEN:

"*... It is difficult to envisage India, moving northwards over such a great distance as an isolated continental mass with its own structural grain, could finally fit neatly into the loose ends of structure in Eurasia ...*" (AUDEN, 1981).

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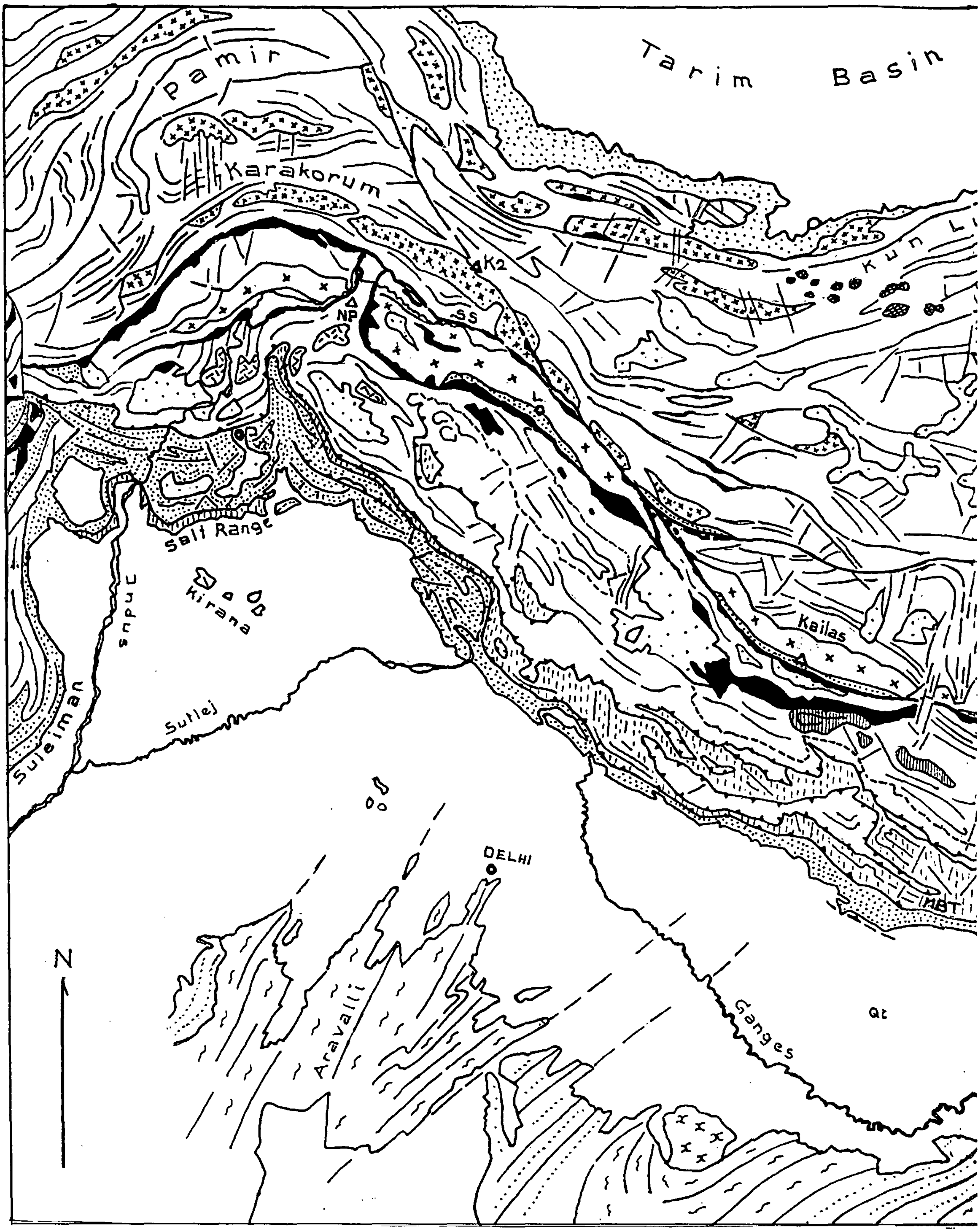

Text-Fig. 5.
Structural map of the larger Himalayas (from GANSSER, 1991).
Note the remarkable differences between the narrow eastern and the wide western "Syntaxis".

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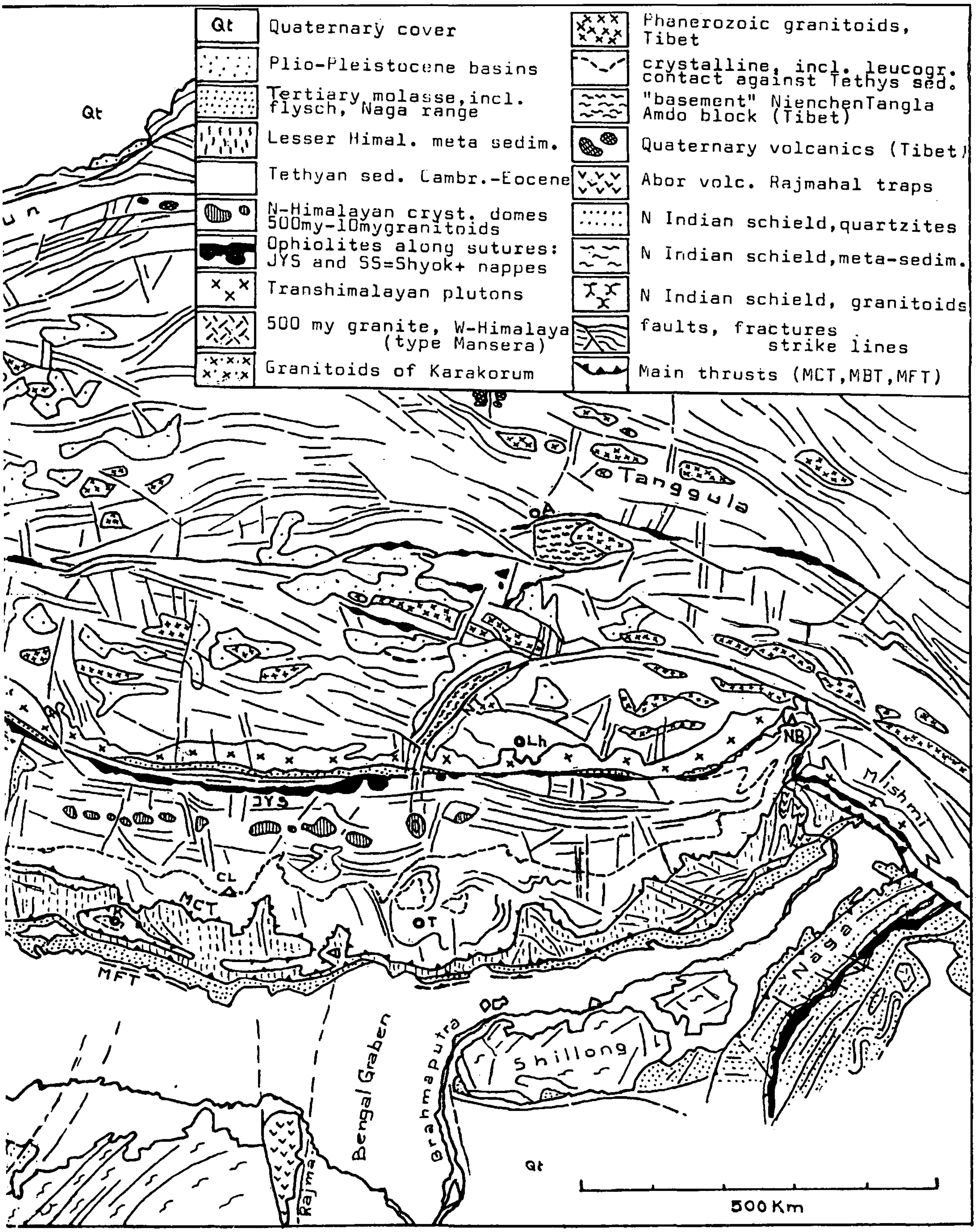

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