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Geological Observations in the Eastern Zanskar Area, Ladakh Himalaya

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ABSTRACT

East of the Zanskar river (Ladakh), the Indus Suture Zone separates the north Indian border nappes of Gondwana from the peri-Gondwana elements of Trans-Himalaya. During geological investigations between the Indus and the Tsarap, we have found 4 major tectonic subdivisions :

—the Ladakh and molasse units north of the suture zone;
—the suture zone with Dras-Nindam and Markha units, the last one being correlated with the Lamayuru nappe of Bassoullet *et al.* (this volume);
—the Nimaling-Tso Morari metamorphic unit (northern Crystalline) with Langtang overlying metasediment group;
—the Zanskar units comprising four units of Tethyan sediments and the southern Crystalline with its palaeozoic metasedimentary cover.

New data on the stratigraphy and the structures on this partly unexplored area are given.

I. INTRODUCTION

Geological observations between the upper Indus valley and the Tsarap east of the Zanskar river have shown the following structural units :

1. the Ladakh unit comprising the Ladakh batholite and the autochtonous molasse;
2. the allochthonous molasse and flysch unit,
3. the Dras-Nindam unit;
4. the Markha unit;
5. the Nimaling-Tso Morari complex unit;
6. the Zalung Karpo unit:
7. the Khurna unit;
8. the Zumlung unit;
9. the Zangla unit;
10. the Ringdom-Phugtal unit (part of the high Himalayan slab).

Very few geological studies were concerned with the whole of the area except Stoliczka (1865) and Lydekker (1880, 1883). Dainelli (1935) gives some indications on the Markha valley and more recently Pal *et al.* (1979) studied the molasse belt, south of Leh. We present here the first geotraverse from the Zalung Karpo La to Zangla, and the different units are studied along a crossing from Martselang on the Indus to Tungri on the Doda. A complete geological report would be given in French by Baud *et al.* (in preparation).

II. THE UNITS NORTH OF THE SUTURE ZONE

The Ladakh Unit

Many recent studies have analysed the Ladakh batholite and its autochthonous sedimentary cover (cf. Frank

et al. 1977; Sharma *et al.*, 1979; Pal *et al.*, 1979; Srikantia *et al.*, 1980). The transgressive levels of the molasse on the meta-granodiorite were recently illustrated by Frank *et al.* (1977, Figs. 3, 4, 8) and by Sharma *et al.* (1979, Figs. 8, 9, 10). The age of this transgression is now still in dispute, Upper Aptian for Bassoullet *et al.* (this vol.), Cenomanian for Srikantia *et al.* (1980), Senonian for Dainelli (1935) and Mio-Pliocene for Pal *et al.* (1977). We have no new data on this unit.

The Allochtonous Molasse and Flysch Unit

This unit is thrusted northward on the autochthonous molasse (Basgo-Upshi Thrust of Pal *et al.* 1979). In the area between Indus and Markha valley, we recognise nine lithological subdivisions (2-6 in Fig. 2, description in Baud *et al.*, in preparation). The Hemis (2) and Stok Kangri (5) formations are conglomertic (conglomerate layers rhytmically repeated) with limestone pebbles containing Nummulite (post-Early Eocene). In the area of Gongmaru La, a red, continental molasse (6) with rain and birdfoot prints caps this allochthonous molasse and flysch unit.

III. THE SUTURE ZONE UNITS

The following two units form the suture zone s.s. outcrop on the right flank of the Markha valley :

(i) The Dras Nindam Unit

This composite unit (7 in Fig. 2) comprises :

(*a*) flyschoid sediments with calc-schists and volcanic microbreccias;
(*b*) polygenic coarse breccias with volcanics, radiolarites and brecciated carbonates with large foraminifera (Nummulites?);
(*c*) coloured melange with ultramafics and exotics.

Well-developed W of the Zanskar river, this unit disappears eastward and does not reach the upper part of the Markha valley (Fig. 1). The contact with the molasse belt consists of a major thrust locally with numerous ophiolite lenses (3 in Fig. 1).

(ii) The Markha Unit

All along the right flank of the Markha valley we have a flysch unit (8 in Fig. 2) with highly deformed marble boulder blocks and limestone lenses. We think that the calcareous schists with boudins of dark marble reported by Kelemen *et al.* (in press) north of Chilling on the Zanskar river correspond to the Markha flysch. This flysch is bounded by deep angle faults from the Dras and Nimaling adjacent units. The microfacies of the limestone lenses consist of recrystallised peloides-ooides skeletal packstones to grainstones. Often graded, these elements are resedimented from an adjacent shelf. One thin section shows a rich microfauna with calcareous algae and *Lucasella cayeuxi* (Lucas) indicating an early Dogger age (det. R. Wernli). This new data is significant in that it enables us to correlate this unit with the Lamayuru flysch recently described by Bassoullet *et al.* (1981). These authors have found the same microfauna in lenses of allodapic limestones near Lamayuru. Thus we can state the great extension of the Triassico-Jurassic flysch along the suture zone and the structural and paleogeographical importance of this unit.

IV. THE NIMALING COMPLEX UNIT

This unit is made of a crystalline gneissic basement, with metagranite intrusives in a cover of sedimentary quartzites and dolomites. In tectonic contact, a thick metasedimentary series of calcareous schists, grits and shales (the Langtang Group, 9 in Fig. 2) can be observed.

(i) The Crystalline

It is a domal body of metagranite and gneiss outcrops in the SE part of the upper Markha valley (3 in Fig. 3). We have found three major types of rocks :

Fig. 3). We have found three major types of rocks :

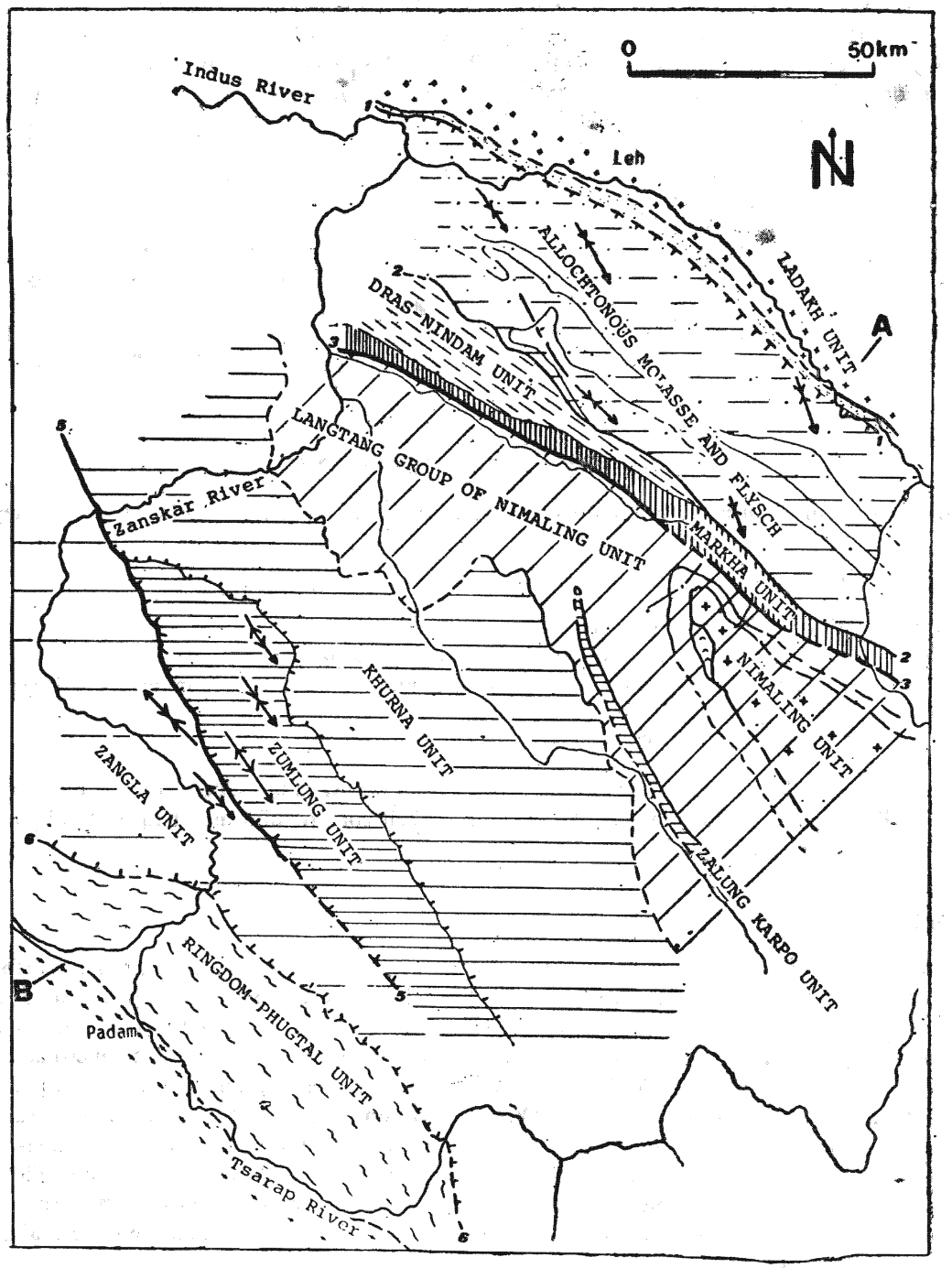

Figure 1. Structural sketch map of the eastern Zanskar. **A-B** : location of the structural cross section of Fig. 2. **1**—Basgo-Upshi Thrust. **2**—Kanda La-Gongmaru La Thrust. **3**—Skiu-Lato fault. **4**—Nimaling-Langtang Thrust. **5**—Zangla Thrust. **6**—Thonde-Phugtal Thrust.

(*a*) banded gneiss that we correlate with the Puga Formation of Sah (1980);
(*b*) metagranite intrusive with pegmatitic apophyses that we correlate with the Polakongka La Granite of Sah (1980);
(*c*) metabasic rocks in the western part of the massif.

(ii) The Metasedimentary Cover

Quartzites and dolomites with granitic veins and apophyses overlie the crystalline, the relationship between the intrusive and the metasediments being shown in Fig. 4.

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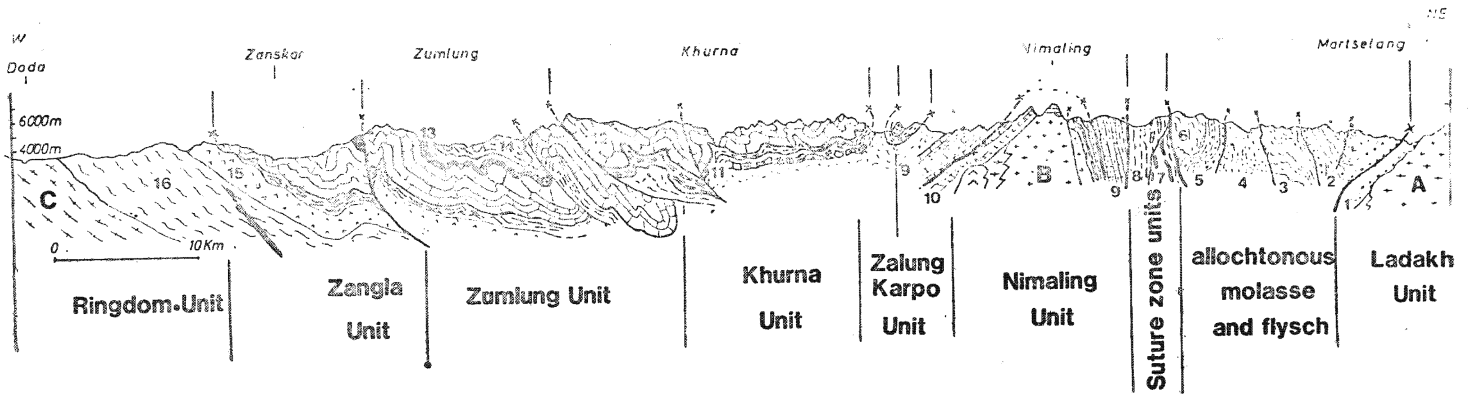

Figure 2. General cross-section through eastern Zanskar from Martselang to Tungri. A—Ladakh (Transhimalayan) batholite. B—Nimaling Crystalline. C—Great Himalayan (Central) Crystalline. 1—Autochthonous molasse. 2—Hemis conglomerates. 3—Sumdo red molasse. 4—Chogdo Flysch. 5—Stok Kangri conglomerates. 6 - Gongmaru-La continental red molasse. 7—Dras-Nindam Series. 8—Markha Flysch. 9—Langtang meta-sedimentary group. 10—Quartzite and dolomite series. 11—Lilang Group. 12—Kioto Group. 13—Spiti and Giumal Formations. 14—Chikkim Formation and (?) Kangi La Flysch. 15—Panjal Traps. 16—Phe Formation.

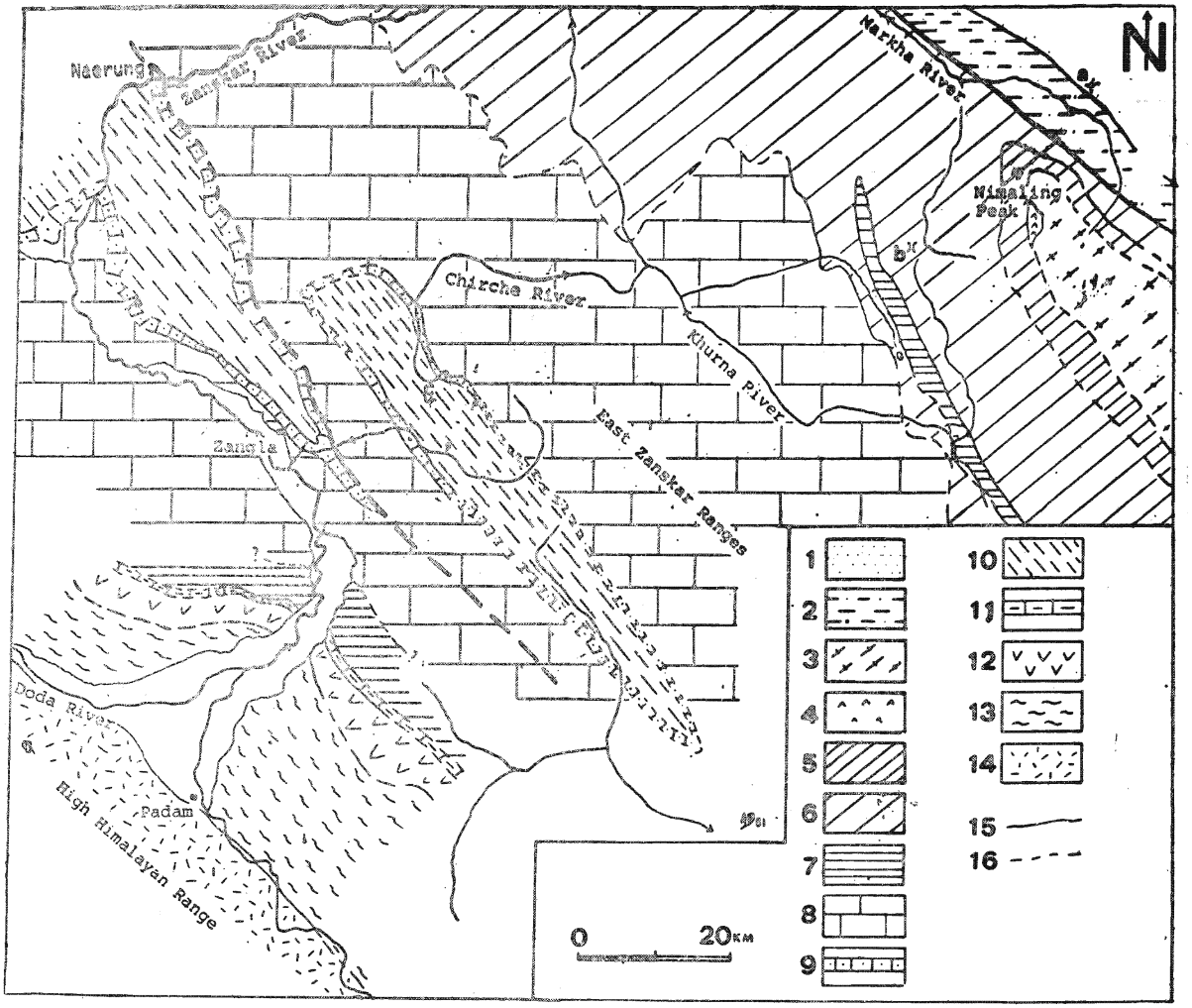

Figure 3. Geological sketch map of the eastern Zanskar, SW of the Markha valley. 1—Gongmaru-La continental red molasse. 2—Markha Flysch with lower Dogger Limestones lenses. 3—Nimaling Crystalline : gneisses with intrusive meta-granite. 4—Nimaling basic massif. 5—Meta-quartzite and dolomite serie. 6—Langtang meta sedimentary group (Upper Palaeozoic ?, mesozoic?) 7—Part of the Lilang Group (Lower to Upper Trias). 8—Kioto Group (Uppermost Trias-Lower Dogger). 9—Spiti Shales and Giumal Sandstones (Upper Jurassic-Lower Cretaceous). 10—Chikkim Limestones and(?) Kangi La Flysch (Upper Cretaceous). 11—Supra Panjal Traps shales (Zewan Formation(?) of the Upper Permian). 12—Panjal Traps (Upper Carboniferous(?)-Lower Permian). 13—Phe Formation (Lower Palaeozoic(?)). 14—Great Himalayan Crystalline (Suru Formation or central gneisses.) 15—Geological or structural line, observed. 16—Geological or structural line, ERTS deduced. a—Gongmaru La; b—Zalung Karpo La; c—Chirche La.

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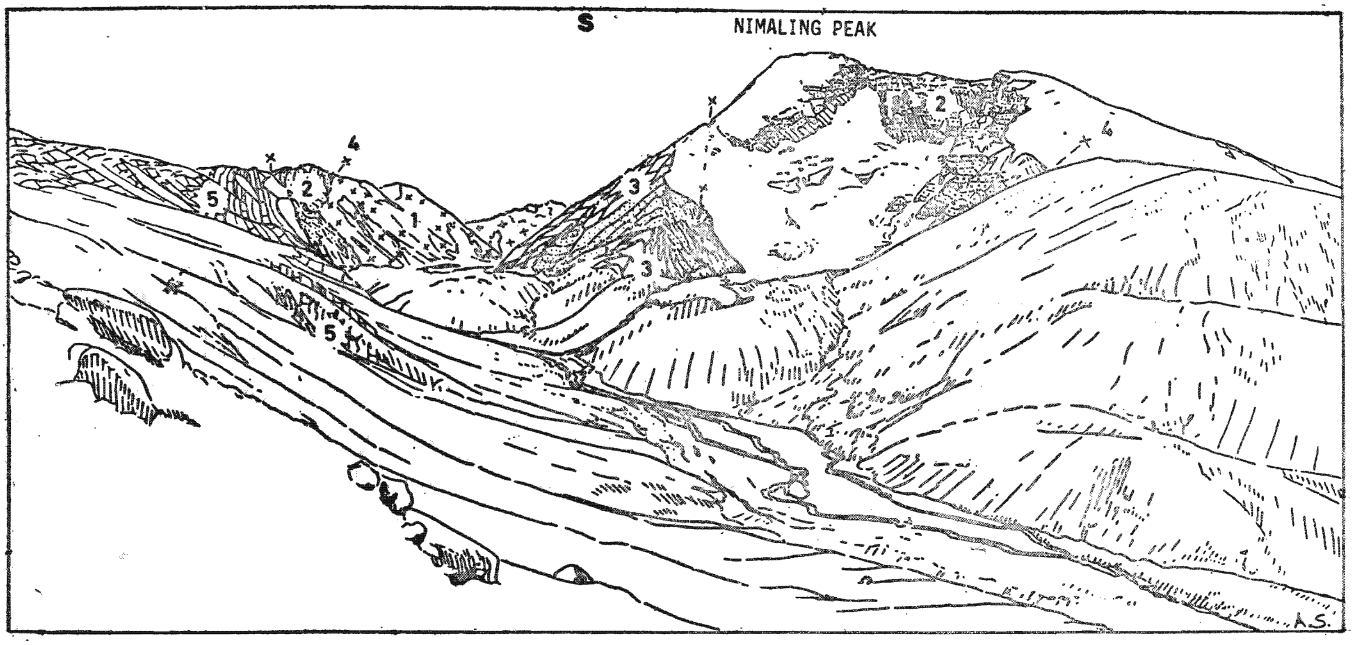

Figure 4. The Nimaling Peak area from the north. **1**—Nimaling meta-granite. **2**—Meta-quartzite with rare dolomitic beds. **3**—Dolomitic marble. **4**—Post-metamorphic fault. **5**—Basal part of the Langtang meta-sedimentary group.

(iii) The Langtang Group

In tectonic contact with the underlying quartzites and dolomites, this metasedimentary group plays an important structural role as shown in Plate I and Fig. 1. About 3 km-thick, this group is formed by at least five formations (Fig. 5). The almost total lack of fossils does not allow us to give an age, nor to accept or reject the Upper Palaeozoic age given eastward along the Leh-Manali road by Gupta *et al.* (1970). This group outcrops along the left flank of the Markha valley from the Nimaling massif to the Zanskar river. We interpret the metasediment accompanied by a sudden increase in metamorphic grade reported by Kelemen *et al.* (in press) along the Zanskar river as corresponding to Langtang Group, and not to Kioto or younger formations. West of the river, we think that the Langtang Group disappears under the Shillakong nappe of Bassoullet *et al.* (this volume). Vertically exposed in the Markha valley (root zone), this group envelops the Nimaling Massif and southwestward underlies the Zanskar units (Plate I).

V. THE ZANSKAR UNITS

On crossing the mountain ranges between the pass of Zalung Karpo and the village of Zangla in the Zanskar valley, we were surprised to discover several tectono-morphological units consisting of Tethyan sediments ranging from early Triassic to late Cretaceous.

(i) The Zalung Karpo Unit

This unit overlies the calc-schists of the Langtang Group and outcrops directly southwestward of the Zalung Karpo La-Yar La pass zone. The strong deformation of the whole of the calc-schists sequence does not allow the determination of the nature and the exact position of the base contact. In the lower part of the unit, the presence of *Posidonia* sp. and *Claraia* sp. (det. B. Gruber) indicates an early Triassic age. In the upper part, corals, limestones and dolomites were found (see profile in Fig. 6). We correlate this series with a part of the Lilang Group of Spiti (Stoliczka, 1865).

(ii) The Khurna Unit

This strongly folded unit is composed of Kioto Limestones about 1500m-thick. The basal part consists of braun weathering limestones and shales of the upper Lilang Group where two Ammonoidea were found : a Tibe-

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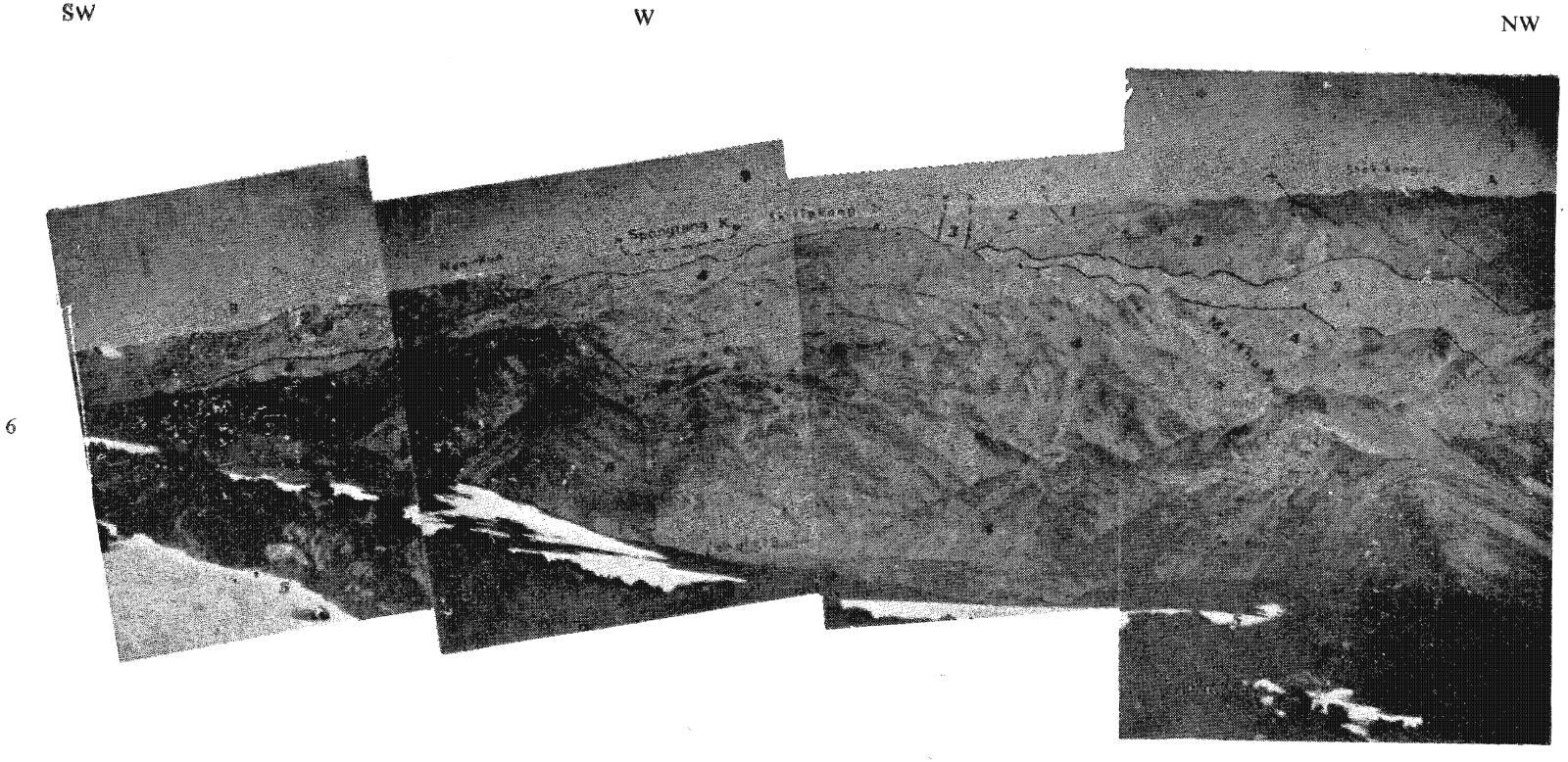

Plate I. Panoramic view of the suture zone, the Nimaling and Zanskar units westward of the Nimaling Massif. **A**—Ladakh Range. **B**—Great Himalayan Range. **1**—Stok Kangri molasse. **2**—Dras-Nindam unit. **3**—Markha unit. **4**—Langtang Group of the Nimaling unit. **5**—Quartzite of Nimaling. **6**—(On the right) Zalung Karpo unit. **7**—Khurna unit.

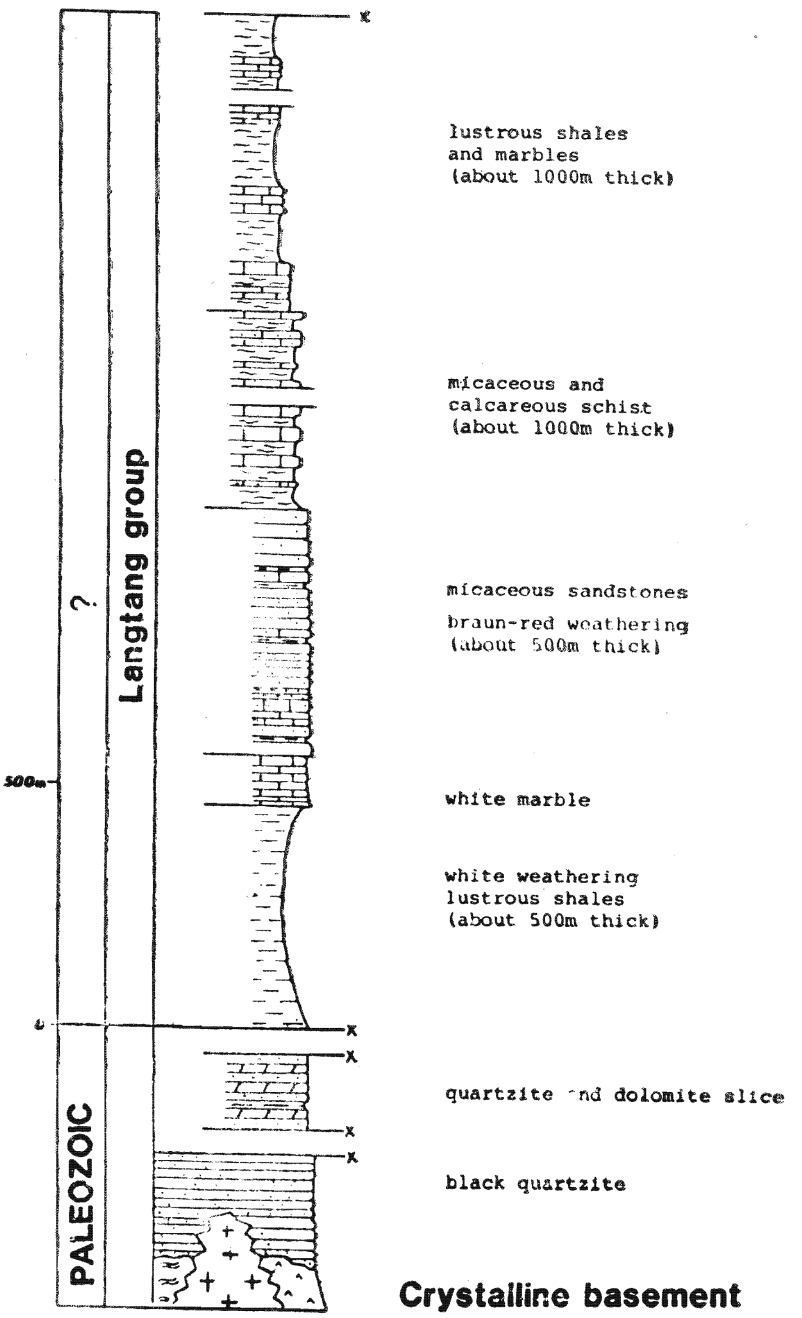

Figure 5. Lithologic column of the Nimaling unit.

tide and *Bihatites bihatiensis* (Diener, 1923) of the Subcolombianus zone (Alaun II, upper Norian, det. F. Tatzreiter). Directly above, the massive Kioto Limestone begins with coral limestones containing *Heterastidium* sp. (basal Rhetian). The Kioto Group is subdivided into two formations (Fig. 7) : the Para Formation with the Megalodons limestones and the Tagling Formation with the Lithiotis limestones (cf. Gupta, 1976) in the lower part and the Belemnite beds in the upper part. Between the two formations there occur emersive levels, locally with palaeokarstic features. Westward, this unit crosses the Zanskar river (Kelemen *et al.* in press) and forms the Zanskar-Shillakong Nappe of Bassoullet *et al.* (this volume).

(iii) The Zumlung Unit

Crossing this unit, we were surprise to discover in the upper Chirche valley a late Jurassic to late Cretaceous

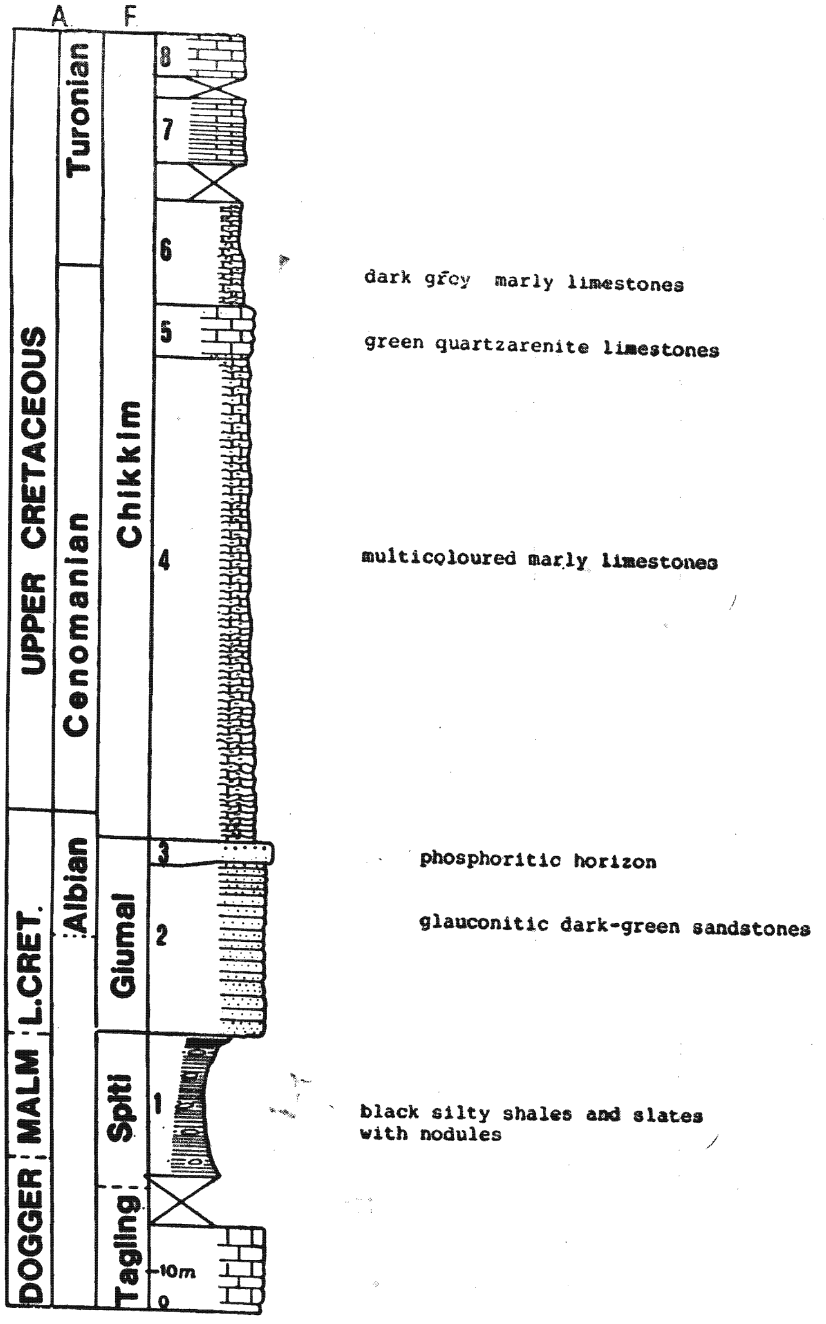

Figure 6. Stratigraphical column of the Zanskar units.

sequence with the Spiti Shales, the Giumal Sandstones and the Chikkim Limestones (Plate II). A stratigraphical profile is given in Fig. 8. The uppermost beds of Giumal Sandstones and the Chikkim Limestones contain a rich planctic foraminiferal fauna (det. M. Caron; list in Baud *et al.*, in prep.). The lowermost beds of the Chikkim Limestones are assigned the late Albian age. They are ovelain by green and red-coloured limestones and quartzarenite limestones containing foraminiferal biozones of the Cenomanian and Turonian. The younger sediments were not sampled and we can not correlate these with the late Cretaceous-early Tertiary sequence of the Kangi La-Oma Chu area (Fuchs, 1977; Gaetani *et al.*, 1980; Kelemen *et al.*, in press; Bassoullet *et al.*, this volume). In the Zumlung gorge, east from Zangla, the Kioto Limestones form a large anticline. A lithological profile through the NE flank is given in Fig. 7. The uppermost beds, rich in Belemnites (Laptal beds)(?) contain foraminifera with Valvulinidae of probably early Dogger age (det. M. Septfontaine).

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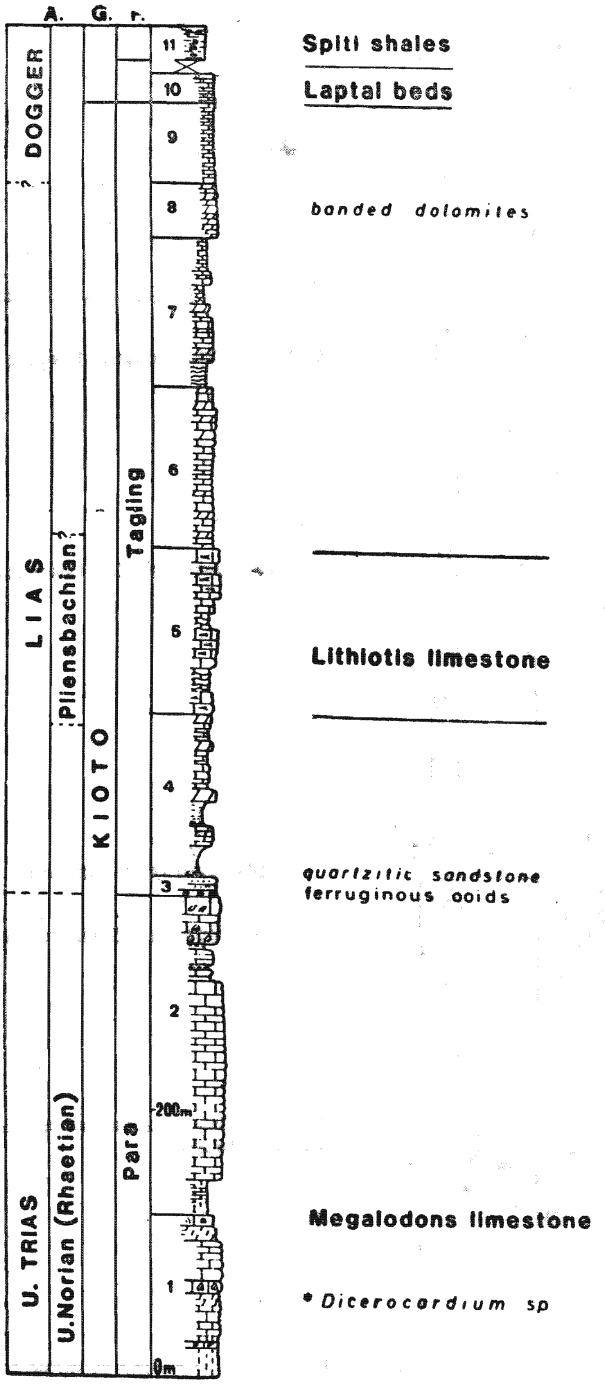

Figure 7. Stratigraphical profile of the Kioto Limestones in the Zumlung Gorge.

(iv) The Zangla Unit

A view of the northern part of this unit is given in Plate III, where we can see a broad syncline with Chikkim Limestones and (?) Kangi La Flysch overlying Giumal Sandstones, Spiti Shales and Tagling Formation of the Kioto Group. The name Zangla Formation for the Triassic rocks of the Zanskar area (Nanda *et al.*, 1976) seems inappropriate to us, because the area of Zangla is entirely made of Jurassic to Cretaceous rocks (see Plate III and Fig. 3). The southern part of this unit is formed by highly folded Kioto Limestones, by the Lilang Group (Figs. 2 and 3) and possibly by the Zewan Formation in the area N of Thonde. The entire unit is overthrusting the Panjal Traps of the Ringdom-Phugtal unit. Northwestward, the Zangla unit crosses the Zanskar river and supports, in the western Zanskar, the Spongtang Ophiolite Klippe (Kelemen *et al.*, in press).

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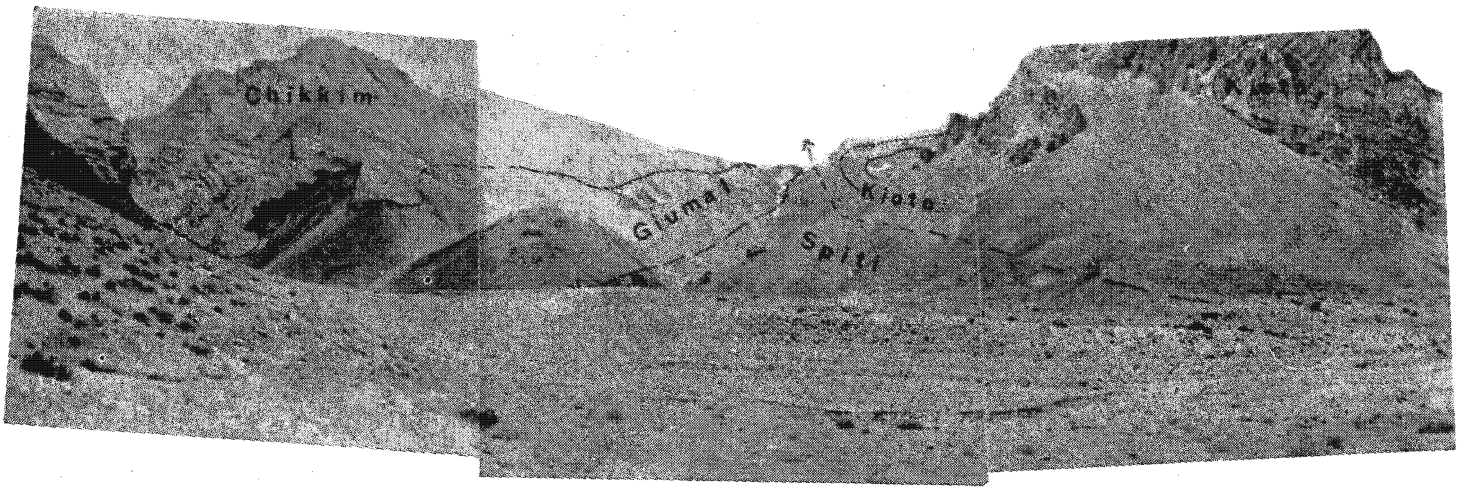

Plate II. Upper Chirche valley (4500m) : Jurassic-Cretaceous sequence of the Zumlung unit.

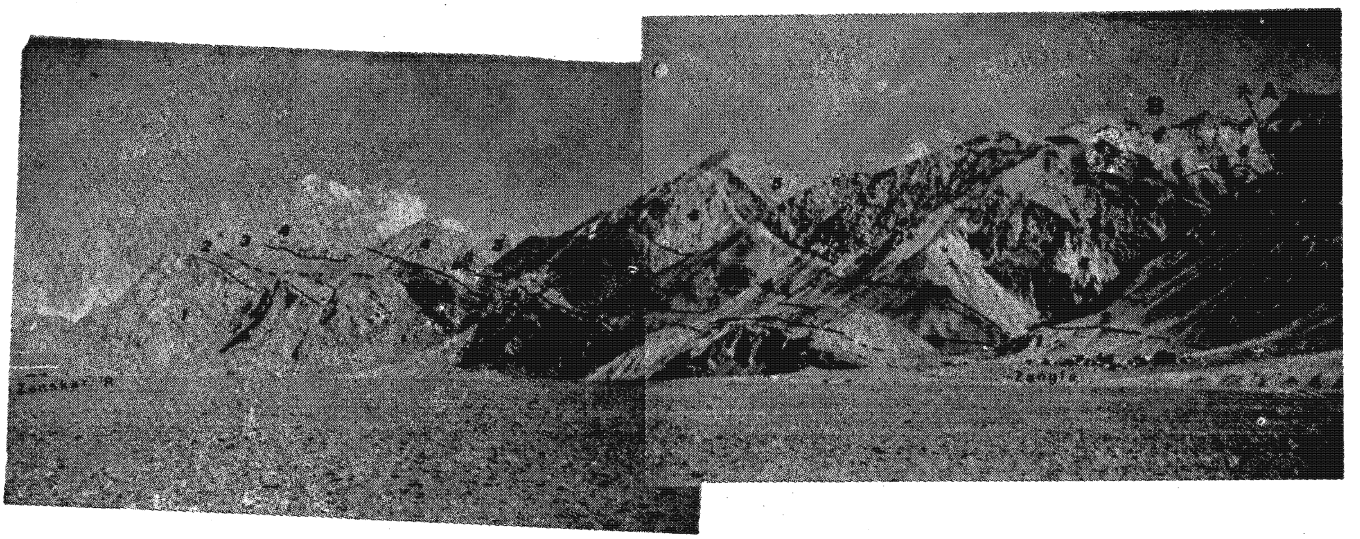

Plate III. General view of the northern Zangla area. **A**—Zumlung unit. **B**—Zangla unit. **1**—Tagling Formation of Kioto group **2**—Spiti Shales. **3**—Giumal Sandstone. **4**—Chikkim Limestone. **5**—Kangi La Flysch?. **X**—Zangla Thrust.

(v) The Ringdom-Phugtal Unit

This unit is a part of the Great or Central Himalaya and is formed by a crystalline basement (Tibetan slab or southern crystalline), by palaeozoic metasediments overlain by the late Paleozoic Panjal Traps. A good description of these series is given by Nanda *et al.* (1976, 1978).

VI. STRUCTURE AND METAMORPHISM

Our observations are too sketchy to propose a chronology of the tectonic and metamorphic events; only the main data are given :

(i) There is a great difference in the grade of deformation and metamorphism between the molassic belt and the suture zone belt. Very low in the autochtonous molasse, the grade of deformation is higher in the allochtonous molasse and flysch unit, with an hectometric open to isoclinal, disharmonic folding accompanied by a subvertical fracture cleavage. The metamorphism is anchizonal. In the Markha unit of the suture zone, we observe an isoclinal folding of an older cleavage and there, the metamorphism reaches the epizone.

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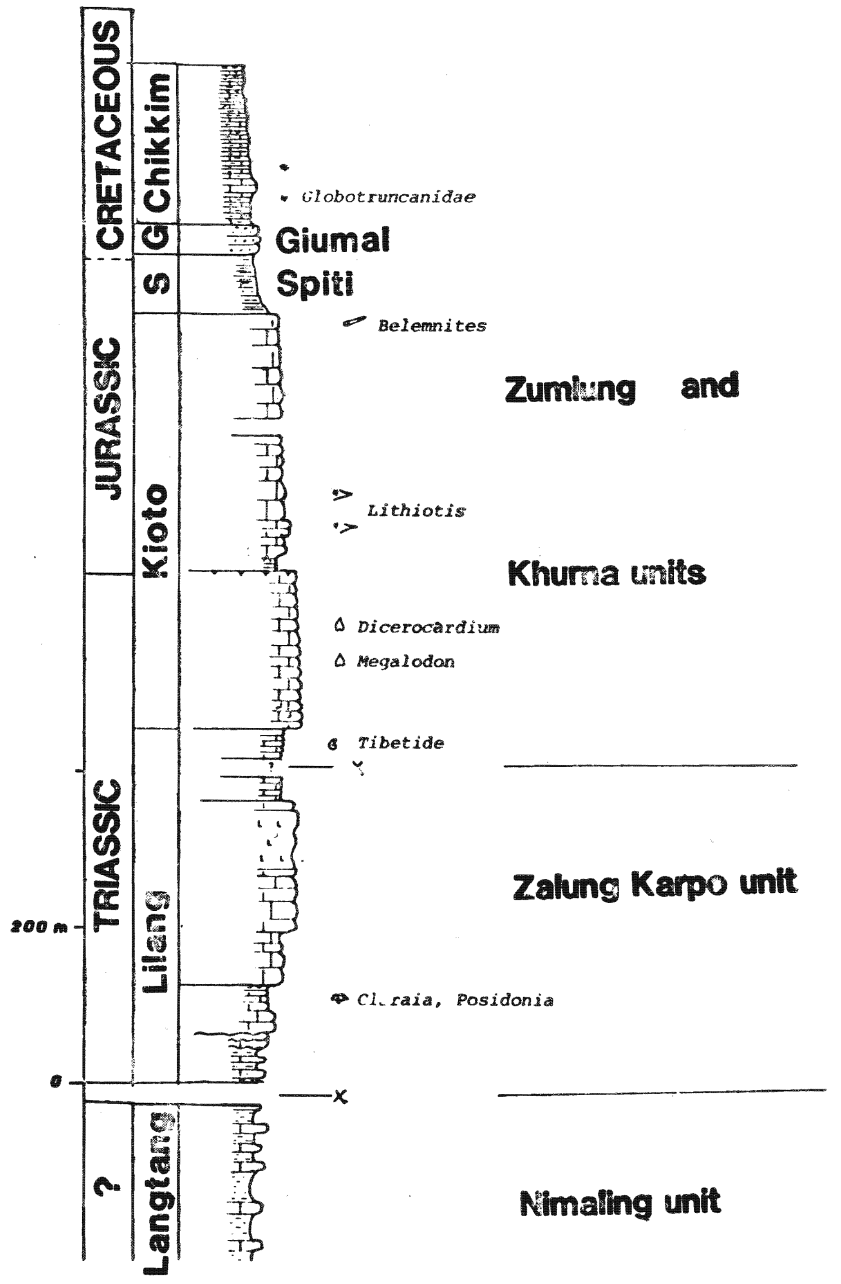

Figure 8. Stratigraphical profile of the Middle Jurassic to Upper Cretaceous series of the Zumlung unit in the upper Chirche valley.

(ii) In the Indus valley, the thrust plane of the allochtonous molasse and flysch unit dips southwestward with a low angle (1 in Fig. 1, and Fig. 2). The suture zone in the Markha valley is bounded by two major structural lines : the Kanda La Gongmaru La Thrust and the Skiu-Lato fault. The latter is correlated with the Zanskar fault of Fuchs (1977, 1979) and Kelemen *et al.* (in press) and has probably an important strike-slip motion (3 in Fig. 1).

(iii) The Nimaling unit shows a regional high epizonal metamorphism super-imposed on a contact metamorphism of the metasediment intruded by the Nimaling Granite. This unit is interpreted as an uplifted block plunging westward (Figs. 1 and 3 and Plate I).

(iv) At least three phases of strong deformations are recorded in the Langtang Group of the Nimaling unit. The structural style along the Markha valley suggests a root zone and the generalized subvertical position of the latest generation of fold axes indicates important horizontal shearing (strike-slip motion of the Skiu-Lato fault).

(iv) At least three phases of strong deformations are recorded in the Langtang Group of the Nimaling unit.

(v) The northern Zanskar units show deca to hectometric kink folds with subvertical axial planes superposed on large isoclinal folds. The metamorphism seems to be decreasing from upper epizone to anchizone, from the Nimaling Massif to the Zanskar units. We interpret the Zalung Karpo unit as a dislocated remnant of the Khurna unit.

(vi) The southern Zanskar units are characterized by the great development of chevron folding. The Zumlung unit consists of a large syncline plunging southeastward and bordered by two southwestward overturned anticlines (Figs. 1, 2, and 3). In the NE, the Kioto Limestones of the Khurna unit overthrust this unit and in the SW we have a major structural line : the Zangla thrust (5 in Fig 1). This thrust crosses the Zanskar river near Naerung (Kelemen *et al.*, in press) to join the Kangi-Shingo La main thrust.

(vii) The highly folded Zangla unit overthrusts the Panjal Traps along a northward dipping folded thrust plane.

In conclusion, the Gondwana-peri-Gondwana contact appears here to be more complex than supposed until now, with the presence of nappes and structures showing late transcurrent movements. This key eastern Zanskar area needs further detailed researches with correlative fossil finds to allow a new model of geodynamic evolution.

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