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UPPER TRIASSIC-LOWER JURASSIC STRATIGRAPHY AND PALEOGEOGRAPHIC EVOLUTION OF THE ZANSKAR TETHYS HIMALAYA (ZANGLA UNIT)

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Riassunto. La successione triassico superiore-giurassico inferiore dell'unità tettonica di Zangla (Ladakh, Himalaya) raggruppa tre principali unità stratigrafiche. Il Carnico superiore è rappresentato dalla Formazione di Zozar, il Norico dalla Quartzite Series, gran parte del Retico e il Lias-Dogger basale dal Gruppo di Kioto.

Il membro inferiore della Formazione di Zozar è caratterizzato alla base da calcareniti con Crinoidi e Briozoi e poi da alternanze di calcareniti e calcari marnosi di ambienti subtidale aperto e di rampa carbonatica. Il membro superiore della stessa unità si distingue per le litofacies carbonatiche peritidali e di laguna interna.

Nella Quartzite Series sono stati riconosciuti tre membri: l'inferiore con arenarie quarzoso-feldspatiche e ironstones oolitici, il medio con fanghi carbonatico-pelitici di shelf esterno e il superiore costituito da sequenze regressive di calcareniti e di arenarie quarzose.

Nell'ambito delle due formazioni del Gruppo di Kioto (Para e Tagling) sono state individuate otto litozone informali. La Formazione di Para si caratterizza per i carbonati subtidali con frequenti episodi tempestitici e subordinati apporti terrigeni. La Formazione di Tagling, più potente, consiste di sequenze decametriche carbonatico-pelitiche di shelf da interno ad aperto con alla base frequenti calcari marnosi o marne e prevalenti strati calcarenitici di tempesta alla sommità. La porzione sommitale del Gruppo di Kioto, a NE probabilmente di età Dogger Inferiore, è caratterizzata da sottili intercalazioni di quarzareniti costiere. L'intera successione è ovunque troncata da una discontinuità regionale.

Le unità studiate si sono deposte nella porzione interna della piattaforma, in prevalenza di bassa profondità, appartenente al margine passivo della Placca Indiana. Questa piattaforma, dominata da eventi

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tempestitici, si approfondiva gradualmente verso NE, con passaggio laterale delle successioni studiate a facies di shelf esterno e alle unità bacinali trovate nelle regioni di Khurnak e Markha. La velocità media di sedimentazione delle unità norico-retiche si mantenne attorno a 20 m/m.a; per la porzione liassica del Kioto essa si ridusse a circa 11 m/m.a. Le più alte velocità nel Triassico Superiore e gli incrementi negli apporti terrigeni erano probabilmente connessi con i fenomeni di ringiovanimento dello scudo Indiano a meridione e con l'incremento della subsidenza legata alla tettonica distensiva, che interessò larga parte del Gondwana settentrionale.

Abstract. The Upper Triassic-Lower Jurassic sedimentary succession of the Zanskar Tethys Himalaya (Ladakh, India) can be subdivided into three stratigraphic units: the Zozar Formation (Late Carnian), the Quartzite Series (Norian) and the Kioto Group (Rhaetian to Early Dogger).

The lower member of the Zozar Formation contains basal calcarenites with crinoids and bryozoans, passing upward to intrabioclastic calcarenites and marly limestones deposited in open subtidal to carbonate ramp environments. The upper member is characterized by oolitic peritidal carbonates and shallow lagoonal sediments.

The Quartzite Series consists of a lower member containing nearshore quartzo-feldspathic sandstones and oolitic ironstones, a middle member characterized by offshore muds, and an upper member consisting of regressive calcarenites and quartzose sandstones.

In the Kioto Group (Para and Tagling Formations) eight lithozones have been recognized. The lower unit (Para Fm.) contains shallow-water carbonates with storm layers and subordinate fine siliciclastic detritus. The upper unit (Tagling Fm.) mainly consists of decametric sequences, with marly limestones or marls at the base and prevalent calcarenitic storm layers at the top. The uppermost part of the Kioto Group toward north-east is probably Early Dogger in age and characterized by coastal hybrid quartzarenite intercalations. The top of the unit is invariably truncated by a major unconformity.

This succession, belonging to the Zangla tectonic unit, was deposited in the inner shallow-water part of the northern passive margin of the Indian Plate. The storm-dominated continental shelf gradually deepened towards the north-east, and the studied units passed laterally to offshore and finally to basinal deposits found in the Khurnak and Markha regions. Average sedimentation rates were around 20 m/m.y. for the Quartzite Series and Para Formation, and slowed down to 11 m/m.y. or less in the Liassic part of the Kioto Group (Tagling Fm.). Higher sedimentation rates in the Late Triassic, coupled with increased terrigenous input, may be related to rejuvenation of the southern Indian Shield and increased subsidence due to extensional tectonics affecting a large part of northern Gondwanaland.

Introduction.

The present paper is part of a continuing research program on the stratigraphic-paleogeographic evolution of the Zanskar Tethys Himalaya. A detailed study of the Upper Triassic-Lower Jurassic succession of Zanskar (Northwestern Himalaya) has been carried out during three expeditions in 1981, 1984 and 1987. The sequence is well exposed and several detailed stratigraphic sections have been measured from Ringdom Gompa to Phirtse La (Fig. 1). The Upper Triassic-Lower Jurassic sequence is part of the Tethys Himalaya zone, which comprises Late Precambrian to early Eocene units (Baud et al., 1984; Gaetani et al., 1986; Garzanti, 1986). Stratigraphic and structural work on the Zanskar sequence has been carried out by Raina & Bhattacharyya (1977), Nanda & Singh (1977), Kanwar & Bhandari (1979), Fuchs (1979, 1982a, 1987), Srikantia et al. (1980), Srikantia (1981), Baud et al. (1982), Bassoullet et al. (1983), Kelemen & Sonnenfeld (1983), Brookfield & Andrews-Speed (1984), Colchen et al. (1986), Searle (1986), Searle et al. (1988).

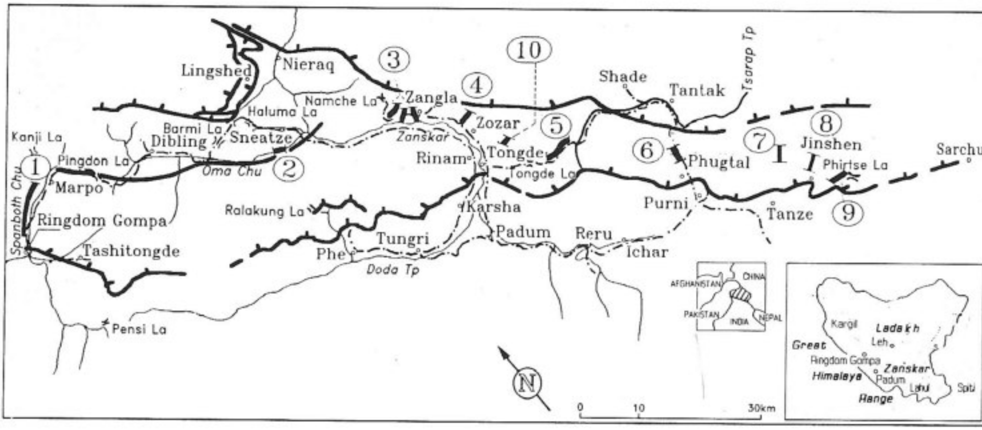


Fig. 1 - Geographic map of the studied Zanskar area, showing itinerary of the 1984 expedition and major tectonic contacts (after Gaetani et al., 1986; Garzanti & Brignoli, 1989). The thick bars indicate the location of measured stratigraphic sections.

Stratigraphy

Fourteen sections have been measured in three main areas from west to east (Ringdom - Tashitongde; Zangla - Tongde La; Tanze - Jinshen) (Fig. 1). All of them belong to the Zangla Unit (Baud et al., 1982). Three lithostratigraphic units have been recognized from bottom to top: Zozar Fm., Quartzite Series and Kioto Group (Baud et al., 1984; Gaetani et al., 1986). Only the Zangla section is complete from the upper Zozar Fm. to the upper Kioto Group. In the measured stratigraphic sections we distinguished 7 main lithofacies groups (A to F) and several sublithofacies.

Lithofacies A. Calcarenites, calcirudites and hybrid arenites.

A1. Light grey, medium to coarse grained, mainly bioclastic packstones-rudstones. Fauna is dominated by crinoids, with locally abundant bryozoans, rare brachiopods and corals. Beds are planar and up to 1 m thick; rarely with erosional base, parallel to cross-lamination or slumpings.

A2. Light grey, fine to medium-grained intra-bioclastic packstones. Planar, up to 2 m, amalgamated beds; erosional base, rare bioturbation and cross-lamination. Associated with lithofacies A1.

A3. Dark grey, medium to fine intra-bioclastic (mainly bivalves, echinoderms and algae) packstones or grainstones. Up to decimetric planar to nodular beds, with hummocky cross-lamination, normal grading, frequent erosional base and clay chips.

A4. Intraclastic-lithoclastic, locally bioclastic calcirudites (rudstones prevalent). Thin horizons associated mainly with lithofacies A3 are often overlain by lithofacies A5 or G1.

A5. Grey to dark grey intra-bioclastic packstones rich in quartz extraclasts, with decimetric thickness and commonly interbedded with lithofacies F3-4 or A3.

A6. Brown to dark pink, rusty, medium to coarse-grained intra-bioclastic ferruginous grainstones often very rich in quartz extraclasts (hybrid quartzarenites). Up to decimetric lenticular bedding, clay chips. Associated with lithofacies A3, A5.

Lithofacies B. Peritidal and shallow subtidal carbonates.

B1. Oolitic-intraclastic packstones or grainstones, locally dolomitized, with megaripple cross-lamination. Beds are planar to lenticular and up to 50 cm thick.

B2. Light grey mudstones-wackestones, subordinate peloidal packstones with oncoids. Typical large bivalves ("alatochonchid" type, megalodontids) in dolomitic limestones. Planar, amalgamated beds up to 2 m.

B3. Dolomitic stromatolitic bindstones with fenestrae. Locally tepee structures or evaporitic voids. Planar, decimetric beds.

Lithofacies C. Biolithites.

C1. Lenticular patch-reef boundstones yielding corals, hydrozoans or bryozoans. Massive bedding up to 3 m.

C2. Biostromal rudstones.

Lithofacies D. Dark bioturbated limestones.

D1. Dark grey bioturbated mudstones with thin planar to nodular bedding.

D2. Dark grey bioturbated intraclastic-peloidal packstones alternating with mudstones-wackestones. Thin planar to nodular bedding.

Lithofacies E. Marly limestones and marls.

E1. Dark grey, locally laminated, thin-bedded marly limestones and marls.

E2. Dark grey thin-bedded bioturbated marly limestones and marls.

Lithofacies F. Siliciclastics.

F1. Fine-grained subarkoses to medium-grained white orthoquartzites with megaripple cross-lamination; bedding up to 2 metres.

F2. Light grey, fine to medium-grained, intra-bioclastic quartzose arenites with cross-lamination or bioturbated. Intraclasts may be dolomitic (F2a).

F3 Grey-green thin-bedded to amalgamated, very fine-grained arkoses to subarkoses, often displaying hummocky cross-lamination or bioturbated; bedding decimetric to metric.

F4. Grey micaceous siltstones, locally containing ammonites (F4a).

Lithofacies G. Ironstones.

G1. Poorly sorted, black to dark brown, calcite-cemented microruditic ironstones with abundant chamosite/goethite iron ooids, pebble-sized lithoclasts (subarkoses, hybrid arenites, intra-bio-calcarenites, siltstones rich in organic matter) and varied fossils (echinoderms, brachiopods, pelecypods and gastropods); bedding centimetric to metric.

G2. Chamositic or phosphatic, dark greenish-grey pelites to fine grained arenites.

Details of stratigraphic sections, with sedimentary structures and microfacies are given in Tab. 1, 2, 5.

Zozar Formation.

The Zozar Formation has been defined on the basis of data collected during the 1981 expedition (Baud et al., 1984). Further detailed stratigraphic studies have been carried out during the 1984 expedition. The unit crops out continuously from the Ringdom

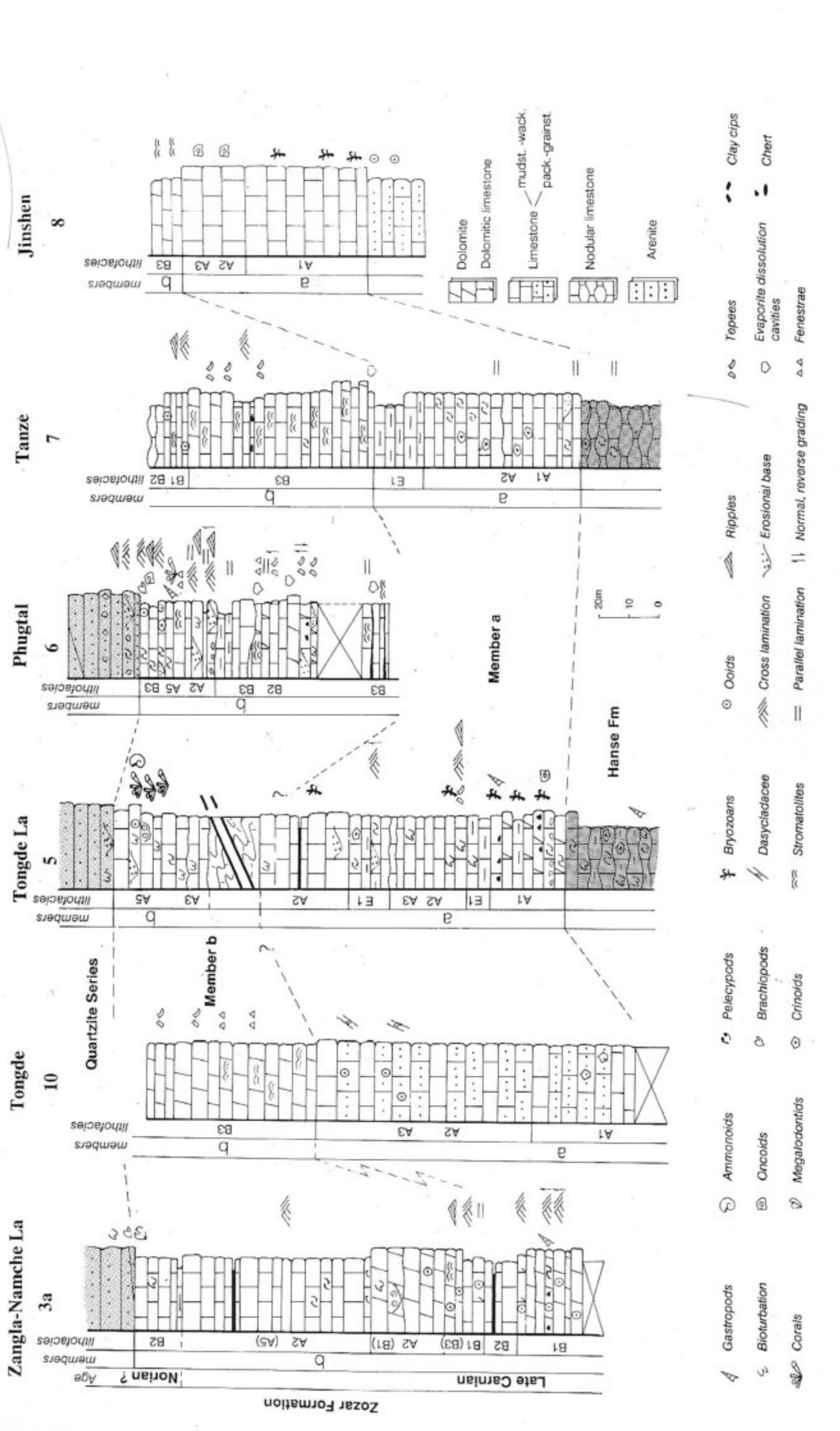


Fig. 2 - Stratigraphic columns and sedimentary structures of the Zozar Formation (Zangla-Namche La, Tongde, Tongde La, Phugtal, Tanze and Jinshen sections; Zangla Unit).

Tab. 1 - Zozar Formation stratigraphic sections.

LITHO FACIES	THICK. m	LITHOZONES	SEDIMENTARY STRUCTURES	MICROFACIES	FOSSILS
		TASHITONGDE SECTION. Base and top not exposed.			
A1 A2/A3 E1	95	a) In the lower part marble horizon with bryozoans. Alternating dark to light calcilutites and calcarenites with marly limestones toward the base.	a) Rare lenticular bedding, erosional base, rare cross and parallel laminations, marly limestones.		a) Bryozoans, pelecypods, rare coral fragments.
B2/B3	60	b) Dolomitic limestones and calcilutites with oncoids and bioclasts.	b) Rare planar stromatolites. Bedding 0.3-1.5 m.	b) Bioclastic packstones.	b) Rare coral fragments, dasycladacean algae.
		ZANGLA-NAMCHE LA SECTION. (Lower member a not exposed).			
B1/B2 (A2/B3)	70	b) Light grey oolitic limestones. Rare dark horizons and stromatolitic layers.	b) Lenticular bedding, erosional base, normal grading, ripple marks and large scale cross-laminations, storm layers.	b) Intrabioclastic pack/grainstones with subordinate bioclasts.	b) Undefined pelecypods, gastropods, echinoids, benthic foraminifers in a few layers: *Aulotortus communis*, *A.* cf. *friedli*, *A. tenuis*, *A.* cf. *sinuosus*.
A2/B2 A5	78	Light grey calcilutites and calcarenites. Scanty sandy intercalations toward the top.	Bedding: 0.1-0.8 m. Rare large scalecross-laminations.	Rare bioclastic wackestones.	Topmost layer: gastropods, pelecypods (*Neomegalodon* sp.).
		ZOZAR SECTION. Base not exposed.			
A2/3	110	a) Light grey dolomitic calcilutites with rare bioclasts. Biocalcarenites/rudites intercalated.	a) Bedding: 0.5-1 m.	a) Mudstones with intercalation of bioclastic pack/rudstones.	a) Echinoderms, pelecypods, brachiopods, rare bryozoans (*Zozariella stellata*, *Dyscritella rhomboporata).*
A2/B3	57	b) Light grey dolomitic calcilutites/calcarenites with frequent stromatolites. Intraclastic breccias.	b) Planar stromatolites, bird's eyes, fenestrae, juvenile tepees.		b) Barren.
		TONGDE (Top not exposed).			
A1/A2 A2/A3	38 75	a) Bryozoan calcarenitic horizon, light to dark grey bioclastic calcarenites, locally with ooids.	a) Erosional base, normal grading, bioturbations.		
B3	55	b)Light grey peritidal dolomites.	b) Stromatolites, fenestrae, tepee structures.		
Tot.	**168**				
		TONGDE LA SECTION (Section formed mainly by lithozone a).			
E1/A3	23	Dark grey marly limestones with calcarenites (Transition to Hanse Fm).	Bioturbation. Bedding: 0.2-0.6 m.	Bioclastic packstones.	
A1 (B2) (E1)	30	a) Grey bioclastic calcarenites, locally dolomitized and subordinate calcilutites and marly limestones. Mud chip horizons at the base.	a) Ripple marks, erosional base, bioturbation and burrowing.	Frequent recrystallization.	a) Echinoderms, gastropods, bryozoans (*Zozariella stellata*, *Dyscritella rhomboporata*).
E1 A3/A2	50	- Dark grey marly limestones, calcarenites intercalated.	-Rare bioturbation.	Bioclastic pack/grainstones. Rare intraclasts.	-Rare bryozoans at the base.
A2	30	- Grey to dark grey bioclastic calcarenites. Subordinate dark calcilutites.	-Erosional base, normal grading, cross-laminations. Bedding up to 6 m, rare bioturbation, erosional base, normal grading.		-Pelecypods, echinoderms, ?udoteacean algae, rare bryozoans in grey calcarenites.
	35	Folded and covered area.			
A3/A5	13	b) At the top bioclastic calcarenites with rare ooids, quartz extraclasts.	b) Bioturbation, erosional base, cross-lamination, normal grading.		b) At the top coral fragments, rare ammonoids
Tot.	**158**				
		TANZE SECTION.			
A1/A2 E1	80	a) Grey to dark grey bioclastic calcarenites and subordinate calcilutites. At the top dark grey marly calcilutites (about 20 m).	a) Erosional base, parallel lamination. Bedding 0.1-0.3 m, amalgamated.	a) Grainst./pack. with dominant spongiostromate oncoids and coated grains (bioclasts).	a) Echinoderms, pelecypods, gastropods, bryozoans (trepostome, cryptostome), rare benthic foraminifers (*Aulotortus friedli*, *A. sinuosus*, rare solenoporacean algae.
B3	77	b) Light to dark grey dolomitic limestones. Abundant stromatolites, mud chip horizons.	b) Planar stromatolites, rare cross-laminations. Bedding 0.5-1 m.	b) Alternation of mudstones and fine peloidal packstones.	
B1/B2		The topmost 10 m are brownish oolitic/bioclastic calcarenites.	Ripple marks, parallel laminations.	Grainstones with ooids, coated grains, bioclasts.	Echinoderms, gastropods, brachiopods, pelecypods, rare benthic foraminifers (*Aulotortus communis*).
Tot.	**157**				
		JINSHEN SECTION (Top not exposed).			
A1	40	a) Basal bryozoan calcarenitic-ruditic horizon.	a) Erosional base. Bedding 0.1-0.6 m.	a) Bioclastic pack/grainstones, intercalated with bioclastic wack. Towards the top oncoids and intraclasts increase.	a) Echinoderms, brachiopods, pelecypods, abundant bryozoans (*Zozariella stellata*, *Dyscritella rhomboporata*, *Tebitopora orientalis*, rare solenoporacean algae, rare coral fragments.
A2/A3	20	Light to dark grey bioclastic oncoidal calcarenites and calcilutites.			
B3	20	b) Grey-white dolomites.	Bedding 0.5-1 m.	b) Stromatolitic bindstones.	
		PHUGTAL SECTION (only lithozone b).			
B2/B3	58	b) Light grey dolomitic peritidal limestones intercalated with calcarenites. At the top calcilutites and marly limestones.	b) Planar stromatolites, fenestrae, evaporitic cavities and breccias, parallel laminations, normal grading, erosional base, bioturb.	b) Intrabioclastic pack./grainst., intercalated bioclastic wack., fenestral pack. and hybrid quartzarenites.	b) Crinoids in calcarenites.
A5 B3 A2	25	Light grey to dark grey calcarenites intercalated with peritidal, ooidal limestones and hybrid arenites.	Erosional base, normal grading, parallel/cross-laminations, ripples, bioturb.	Intrabioclastic pack./grainst. with oncoids, ooids, fenestrae.	Brachiopods, crinoids, coral fragments, pelecypods, gastropods.

Gompa to the Phirtse La area, with its type-area between Zangla and Tongde La. Six stratigraphic sections have been measured (Fig. 2). Unfortunately most of them are only partial sections, since the unit, although well exposed, is invariably tightly folded. The only complete section, measured at Tanze, is quite difficult to reach and highly tectonized. Therefore, two partial type sections are proposed, at the base of Tongde La and along the track to Namche La (Fig. 1, 2), covering respectively the lower and the upper part of the unit.

Lithology.

The upper part of the underlying Hanse Fm. consists of dark nodular thin-bedded marly limestones (lithofacies E2) and limestones (lithofacies D1, A3) locally containing plagioclase and quartz extraclasts, pelagic pelecypods, radiolarians, sponge spicules, echinoderms. The uppermost 10-30 m are richer in crinoids and pass rapidly to the grey planar bioclastic calcarenites (lithofacies A1, A2) of the Zozar Fm. (Fig. 3). A noticeable change of thickness has been detected from west to east (about 400 m in the Ringdom area to about 160 m in the Tanze-Jinshen area).

Five main lithofacies associations, not always present, have been recognized, from bottom to top.

1) Basal grey bioclastic calcarenites-rudites with crinoids (Fig. 3B), bryozoans, brachiopods, rare corals; locally partially dolomitized (lithofacies A1).

2) Dark grey to grey intra-bioclastic calcarenites with echinoderms, pelecypods, locally bryozoans and solenoporacean, or udoteacean algae (lithofacies A2, A3).

3) Discontinuous dark grey marly limestones (lithofacies E1) interbedded with A2, A3 lithofacies.

4) Light grey oolitic carbonates associated with peritidal stromatolitic and rare sabkha dolomites (lithofacies B1, B3).

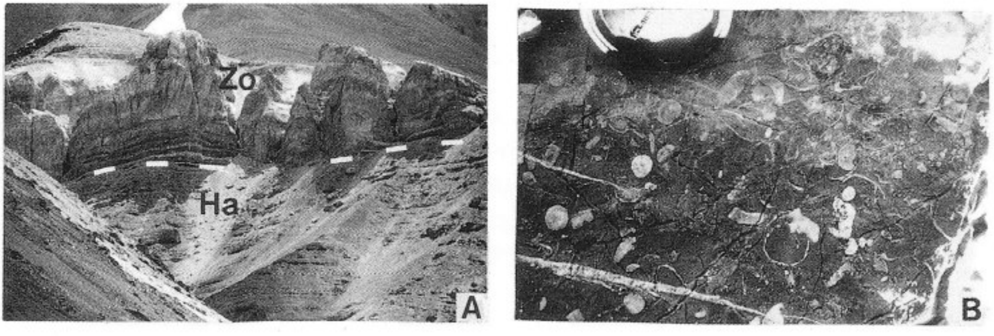


Fig. 3 - Boundary between the upper Hanse (Ha) and Zozar (Zo) Formations (A; Jinshen section), marked by the appearance of bryozoan-rich biocalcirudites and crinoidal wackestones (B; Phugtal section).

5) Light grey calcilutites (lithofacies B2) intercalated with B1 and, only in the Zangla sector, with F2 lithofacies.

The unit can be subdivided into two members (Fig. 2).

The *lower member* (a) is characterized by lithofacies associations 1+2+3. The basal interval rich in crinoids and bryozoans (A1) is typical, but not always present. Thickness is from 70 to 90 m; maximum values are observed east of Tongde La. In the Zangla-Namche La area this member is not exposed.

The *upper member* (b) is characterized by lithofacies associations 4+5. The Zangla section consists of dolomitic oolitic limestones (B1) followed by calcilutites (B2) and calcarenites (A2). Towards the south east (Phugtal-Jinshen area) inner platform intertidal-supratidal sequences prevail (Fig. 4b).

Thickness is from 70 to 150 m. Lithofacies distribution, sedimentary structures and microfacies for each stratigraphic section are synthesized in Tab. 1.

Paleontological content and biostratigraphy.

Faunal and floral content is abundant in member (a). Echinoderms and brachiopods prevail over pelecypods; gastropods and bryozoans are subordinate. However, bryozoans (new genera and species of trepostome and cryptostome: *Zozariella stellata* Schäfer & Fois, 1987; *Dyscritella rhomboporata* Schäfer & Fois, 1987; *Tebitopora orientalis* Zhao-Xun, 1984) (Pl. 38, fig. 5) are abundant (Jinshen, Tongde La) and form a marker horizon at the base of the unit.

Member (b) is poorly fossiliferous; only in the Zangla section oo-bioclastic calcarenites occur. In the topmost layer of the Zangla - Namche La section (Fig. 2, 6b) large megalodontids (*Neomegalodon* sp.) are abundant. Solenoporacean algae (Pl. 38, fig. 6) and benthic foraminifera [*Aulotortus communis* (Kristan, 1957), *A. friedli* (Kristan-Tollmann, 1962), *A. sinuosus* Weynschenk, 1956, *A.* cf. *tenuis* (Kristan, 1957)] are concentrated in few layers of member (a) (Tanze; Pl. 38, fig. 3, 7) and (b) (Zangla-Namche La; Pl. 38, fig. 1, 2, 4, 8). Fragments of undefined colonial corals are present in some sections (Zangla-Namche La, Tashitongde, Tongde La).

The age of the lower member (a) in the Zozar-Jinshen area is probably Late Carnian, as the carnian conodont *Gondolella polygnatiformis* (Budurov & Stefanov, 1965) was found in the lower-middle part of the underlying Hanse Fm. at Jinshen; this finding was wrongly assigned to the Zozar Fm. in Baud et al. (1984, p. 181). Also the bryozoan fauna that characterizes the basal marker horizon is ascribed to the Carnian by Schäfer & Fois, 1987. The Carnian/Norian boundary may occur either in the uppermost Zozar Fm., as suggested by the occurrence of large *Neomegalodon* sp. at the top of the unit in the Zangla area or even within the overlying arenaceous unit.

Depositional environment.

The unit testifies to shallow-water sedimentation in the whole area. The basal portion represents the transition from offshore neritic (Hanse Fm.) to subtidal conditions.

Member (a) is a subtidal carbonate bank (probably a ramp) that passes gradually to outer shelf environments toward the NE and N (transition to the Hanse Fm). In the Ringdom area, cyclic (5-15 m thick) light to dark calcarenite-calcilutite sequences with graded bedding and rare slumpings might be related to the low-angle slope of a carbonate platform. In the Tongde La-Jinshen areas prevalent calcarenites (A1, A2, A3) are indicative of medium/high energy outer environments of the carbonate ramp, also characterized by shallow-water bars and channels with bipolar cross-lamination.

Relatively deeper-water environments are hypothesized east of Tongde La (Tab. 1; Fig. 4). Toward the N and NW (Zangla, Ringdom) more internal shallow subtidal oolitic bars prevail.

Member (b). Intertidal to supratidal conditions ("back reef" facies of Baud et al., 1984) dominate in the south, from east (Phugtal, Jinshen, Phirtse La) to west (Tongde, Zozar) (Fig. 2, 3). The Zangla area and in particular the region east of Tongde La was instead a shallow subtidal, more external, higher-energy zone. Marginal platform and deeper environments are inferred toward the N and NE areas (Fig. 4b).

Paleocurrent directions, scattered from N80° to N150° in cross-laminae of oolitic sands and from N340° to N160° in herringbone cross-bedding, are not sufficient for a detailed coast line reconstruction.

Sea level changes and sequence stratigraphy.

The two members of the Zozar Fm. point to a regressive trend. In particular, member (a) shows development of a carbonate ramp prograding onto the Hanse basin. This paleogeographic evolution could be related to decrease in the rate of relative sea-level rise ("Highstand System Tract" of cycle UAA- 3.2) (Haq et al., 1988).

Deposition of member (b) may coincide with maximum regression. In the Zangla area, shallow subtidal limestones (upper member b, Tab. 1) overlying oolitic facies could be interpreted as the "Lowstand System Tract" of cycle UAA-4 (Haq et al., 1988).

Quartzite Series.

The formational name "Quartzite Series" was introduced by Hayden (1904) in the Spiti region, to describe a some 100 m thick arenaceous succession with subordinate shales and limestones, stratigraphically comprised between the "Monotis Shales" and the Kioto Limestone. Hence, the name was used also in the Lahul and Zanskar regions to designate a no more than 100 m thick arenaceous unit underlying the Kioto Limestone (Gupta, 1976; Raina & Bhattacharyya, 1977; Kanwar & Bhandari, 1979; Fuchs, 1979). Srikantia et al. (1980) and Srikantia (1981) used the junior synonym "Alaror Formation" for the same stratigraphic interval.

The upper Triassic arenaceous section of Zanskar, however, is poor in diagnostic ammonoids or bivalves, up to 260 m thick and not readily correlatable with the stratigraphic units recognized in Spiti (Fuchs, 1982a). Baud et al. (1984) and Gaetani et al.

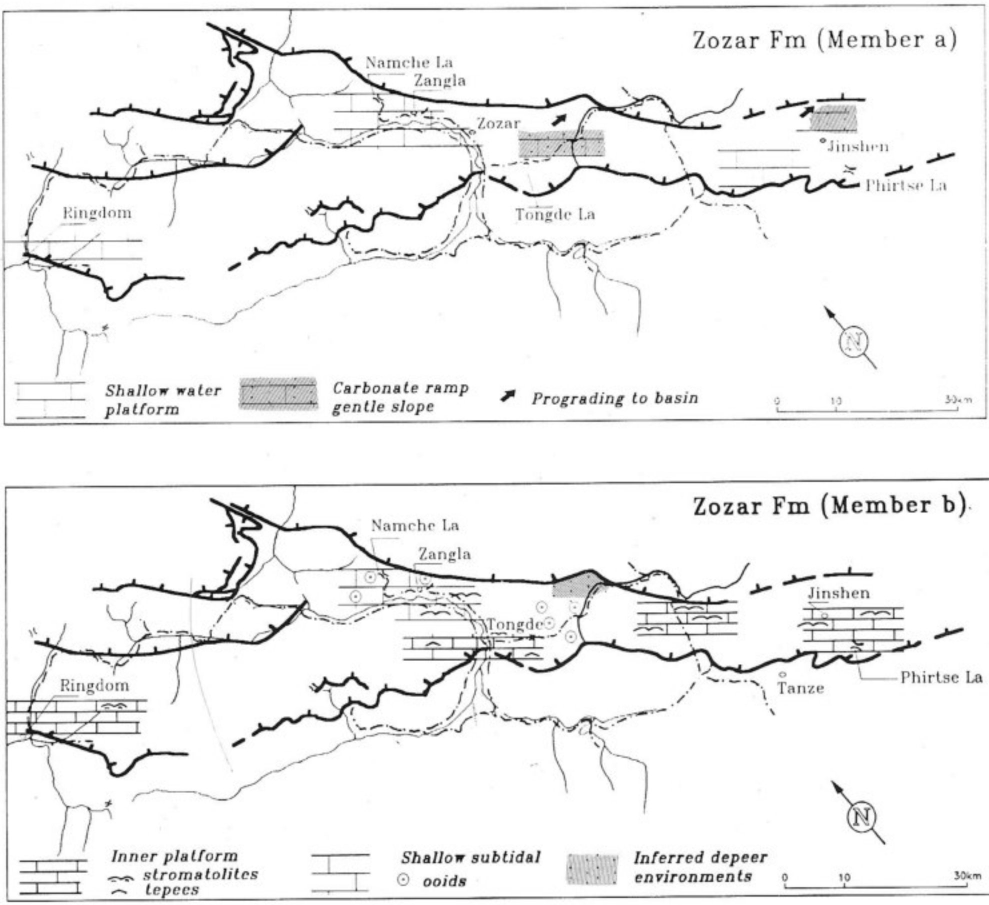


Fig. 4a,b - Paleogeographic sketches for the lower (a) and upper Zozar Formation (b).

(1986) thus adopted the term "Quartzite Series", although improper, to designate the whole sandstone-rich sequence comprised between the Zozar and Kioto carbonate units in the Zanskar region, from Ringdom Gompa to Sarchu.

According to Fuchs (1987), this arenaceous unit would comprise not only the "Quartzite Series", but also the "Juvavites Beds", the "Coral Limestone" and the "Monotis Shales" of Spiti (Hayden, 1904; Fuchs, 1982b) (Tab. 6). This is a good working hypothesis, but, missing any biostratigraphic evidence, we prefer to leave the problem open to alternative solutions and, without introducing confusing new stratigraphic terms, will rather describe in detail measured stratigraphic sections that can be corre-

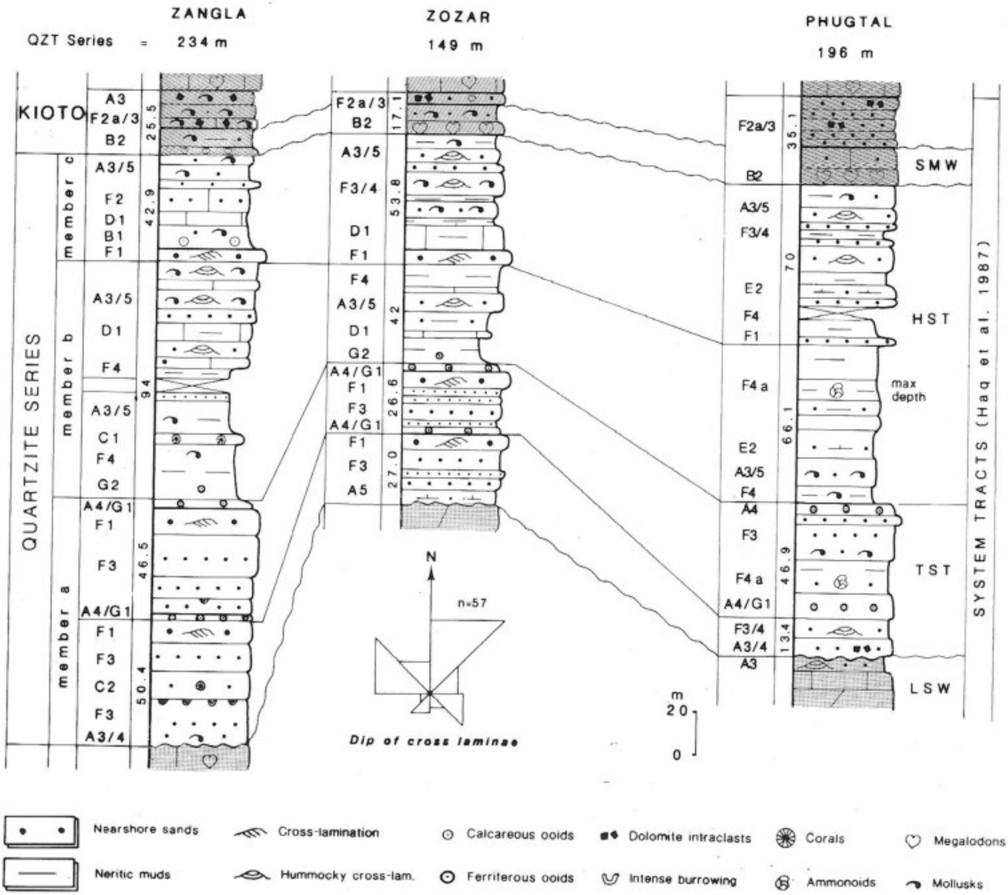


Fig. 5 - Stratigraphic columns for the Quartzite Series (Zangla, Zozar and Phugtal sections; Zangla Unit). Tentative correlations, thickness and predominant lithofacies are indicated for each lithozone. Note lateral continuity of ironstone layers.

lated along the Zanskar region interval by interval.

Five stratigraphic sections were measured in the Zangla Unit (Zangla, Zozar, Phugtal, Ringdom and Tanze). The former three span the complete sequence and were studied in greater detail (Fig. 5). Reduction in thickness in the Zozar section (measured on an overturned anticline limb) and in the Ringdom area is largely ascribed to intense tectonic deformation at anchimetamorphic conditions. Lithostratigraphy, sedimentary structures and microfacies for each section are synthesized in Tab. 2.

Tab. 2 - Quartzite Series stratigraphic sections.

LITHO FACIES	THICK. m	LITHOFACIES ASSOCIATIONS	SEDIMENTARY STRUCTURES	MICROFACIES	FOSSILS
		ZANGLA-NAMCHE LA SECTION			
A1/A3 A4/A5 F1/F3 C2	50	1) Dark grey-green sandstones. Subordinate biocalcarenites and small biolithites. Basal horizon rich in brachiopods and bryozoans. Quartzarenites at the top.	Hummocky cross-lamination, ripple marks, bioturbation. Bedding 0,05-0,6 m.	1) Sandstones: immature arkoses to submature subarkoses. Limestones: bioclastic rudstones, packstones, rare boundstones.	Basal layer rich in brachiopods (*Fissirhynchia fissicostata, Rhaetina* sp.), bryozoans (*Zozariella stellata*, cryptostome), echinoderms, gastropods.
F1/F3 G1/G2 A4	47	2) Dark greenish-grey subarkoses to white quartzarenites. Bio-lithoclastic rudstones and oolitic ironstones at the base and top. (1+2= Member a)	Parallel to high-angle cross-lamination, herringbones, bioturbation. Bedding 0,05-2 m.	2) Sandstones: immature arkoses up to supermature quartzarenit. Limestones: bioclastic packstones, rudstones.	Bivalves, crinoids, gastropods.
A3/A5 D1 F4 C1	94	3) At the base hybrid fine arenites, ferruginous siltstones and coral biolithites. Micritic limestones, micaceous siltstones and hybrid arenites follow. (Member b)	Parallel to hummocky cross-lamination, bioturbation.	3) Limestones: bio-intraclastic packstones, coral framestones.	Bivalves, gastropods, a 2-4 m thick coral patch reef (*Thecosmilia* sp.), locally large megalodontids.
A3/A5 B1/D1 F1/F2/F3	43	4) At the base quartzarenites and oocalcarenites. Greenish-grey arkoses, micritic limestones and hybrid arenites follow. (Member c)	High-angle cross-lamination, ripples, flaser bedding. Bioturbation. Bedding 0,1-1 m.	4) Sandstones: immature arkoses, mature quartzarenites and bioclastic hybrid arenites. Limestones: bio-intraclastic packstones, wackestones, locally boundstones, bioclastic rudstones.	Echinoderms, bivalves, bryozoans, rare corals (*Astraeomorpha crassisepta, Thecosmilia* sp., *Myriophyllia* sp.), spongiomorphid hydrozoans, diffuse udoteacean algae. Benthic foraminifers (*Agathammina* cf. *passerii, Ophthalmidium* sp., *Aulotortus communis, A. friedli*, rare *A. sinuosus*, lagenids). Doubtful specimens of *Triasina* sp.
Tot.	**234**				
A1/A3/A5 B1/B2 F2a/F3	25	5) Micritic to dolomitic limestones with large pelecypods interbedded with quartzose arenites. (Kioto Fm., sublithozone a1).	Hummocky cross-lamination, bioturbation.	5) Sandstones: hybrid quartzose arenites, dolomite intraclasts. Limestones: bioclastic packstones.	Large pelecypods (*Rhaetomegalodon* sp., *Paramegalodus* sp.).
		ZOZAR SECTION			
A3/A4/A5 F1/F3/F4	27	1) Dark greenish-grey sandstones and arenaceous calcarenites; ligther subarkoses at the top.	Hummocky to cross-lamination, bioturbation, rip-up clasts. Bedding 0.05-0.6 m.	1) Sandstones: immature arkoses to submature subarkoses. Limestones: bio-intracl. pack.	
A4 G1/G2 F1/F3/F4	27	2) Dark greenish-grey arkoses and subarkoses to white quartzarenites. Bio-lithoclastic rudstones and major oolitic ironstones at base and top. (1+2=Member a)	Hummocky to megaripple cross-lamination, parallel lamination, bioturbation, rip-up clasts. Bedding 0.05-0.5 m.	2) Sandstones: immature arkoses to submature quartzarenites. Limestones: bio-intraclastic packstones, rudstones, wackestones.	Dominant udoteacean algae (new form similar to *Halymeda*), subordinate echinoderms, brachiopods, benthic foraminifers (*Aulotortus friedli, A. sinuosus*; rare *A. communis, Agathammina* sp., *Glomospirella* sp., *Ophthalmidium* sp.), bivalves.
F4 D1 A3/A5	42	3) Grey micaceous siltstones, ferruginous at the base, micritic limestones and subordinate calcarenites. (Member b)	Hummocky cross-lamination, parallel lamination. Bioturbation.		
D1 A3/A5 F1/F3/F4/F5	54	4) At the base quartzose arenites. Micritic limestones, oo-biocalcarenites, greenish-grey sandstones. (Member c)	Hummocky to megaripple cross-lamination, bioturbation. Bedding 0.1-1 m.	4) Sandstones: immature arkoses up to supermature subarkoses. Limestones: bioclastic packstones, rare ooidal grainstones.	Crinoids, bivalves, gastropods, corals.
Tot.	**149**				
B2 F2a/F3/F4 A5	17	5) Micritic dolomites, limestones with large pelecypods interbedded with orange-weathering quartzarenites (Para Fm., sublithozone a1).	Lenticular bedding, low-angle cross-lamination. Bioturbation. Bedding 0.05-0.8 m.	5) Sandstones: immature subarkoses to submature quartzarenites with dolomitic intraclasts.	Large pelecypods (megalodontids, "alatochonchid-type").
		PHUGTAL SECTION			
A3/A4/A5 F3/F4	13	1) Coarse siltstones, biocalcarenites, hybrid arenites. Locally fenestral, stromatolitic limestones.	Hummocky cross-lam., ripples, parallel lamination, lenticular bedding, bioturb.	1) Limestones: bioclastic, oncoidal packstones, fenestral stromatolitic bindstones.	Gastropods, pelecypods, rare coral fragments, crinoids, brachiopods.
A3/A4 F3/F4/F4a	47	2) Grey-green sandstones and bioclastic calcirudites. (1+2=Member a)	Graded bedding, rip-up clasts. Bioturbation. Bedding 0.05-0.7 m.	2) Sandstones: immature arkoses and subarkoses.	
A3/A5 F4/F4a/E2	66	3) Grey micaceous siltstones, marls and silty calcarenites. (Member b)	Hummocky cross-lamination. Bioturbation.		Rare ammonoids, bivalves.
A3/A4/A5 F1/F3/F4 D1/E2	70	4) Light grey quartzose sandstones at the base. Grey siltstones, biocalcarenites and hybrid siltites. (Member c)	Hummocky cross-lamination. Bioturbation. Bedding 0.1-0.5 m.	4) Sandstones: submature subarkoses.	
Tot.	**196**				
B2/D1 A3/A5 F2a/F3/F4	35	5) Grey limestones with large pelecypods intercalated with orange-weathering quartz, sands with dolomite intraclasts (Kioto, sublithoz. a1)	Megaripple cross-lamination, herringbone structures. Bioturbation. Bedding 0.1-1 m.	5) Sandstones: immature subarkoses with dolomitic intraclasts.	Large pelecypods (megalodontids, "alatochonchid-type").
		TANZE SECTION			
B1/A3 F3	20	1) Well-bedded planar brownish oobiocalcarenites alternating with well bedded brown-weathering sandstones.	Cross-lamination in the oolitic calcarenites.	Limestones: grainst./packstones rich in oncoids and coated grains, abundant quartz extraclasts.	Echinoderms, brachiopods, pelecypods, gastropods, rare bryozoans (trepostome), rare solenoporacean algae, diffuse benthic foraminifers (*Aulotortus friedli, A. sinuosus, A. communis, Auloconus permodiscoides, Auloconus* sp.).
	150	**Total thickness inferred.**			

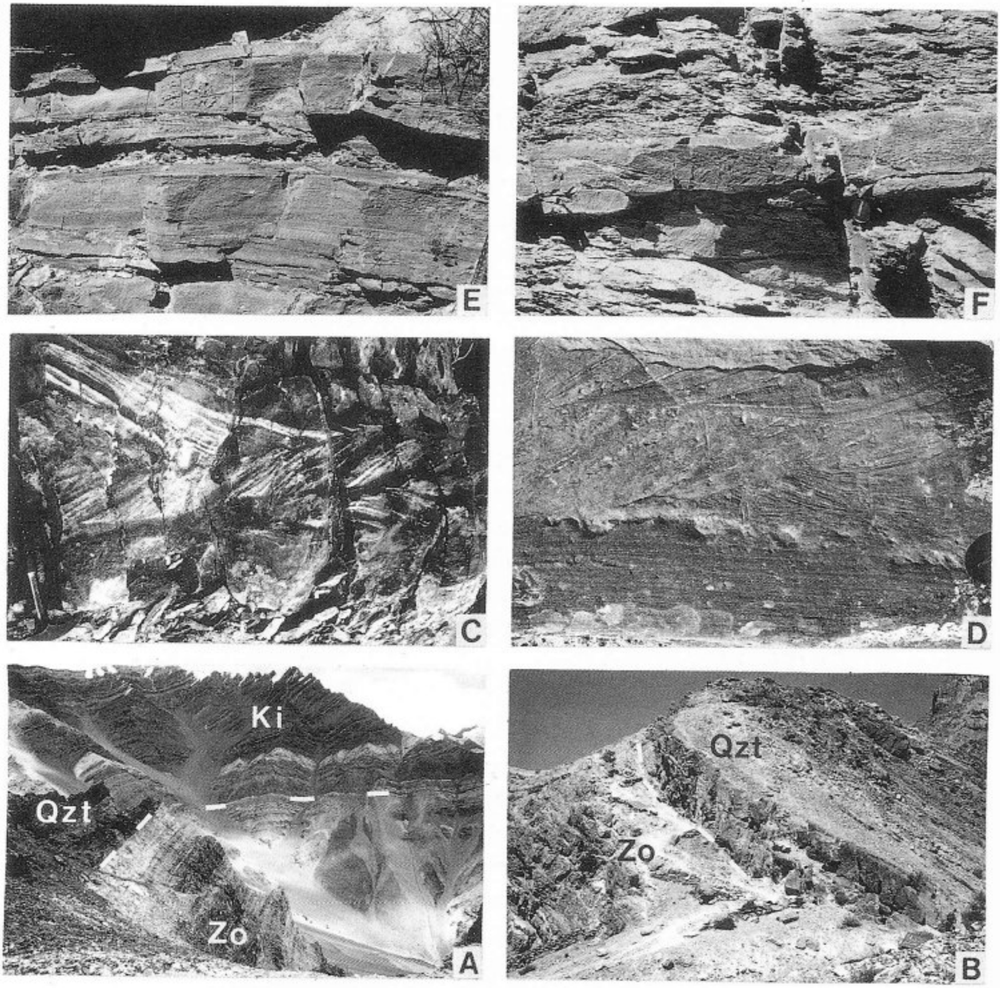


Fig. 6 - Stratigraphy and sedimentary structures of the Quartzite Series. A, B) Sharp paraconformable contact between the Zozar carbonates (Zo) and the Quartzite Series (Qzt) in the Ringdom (A) (note white dolomite at the top of the Zozar Fm.; Ki = Kioto Lst.) and Zangla (B) sections. C) Quartzose calcarenites and quartzarenites (white laminae) with herringbone cross-lamination (A5/F1; member c, Zangla-Namche La section). D) High-angle tangential cross-lamination in upper shoreface quartzarenites (F1; isolated block; Zangla-Namche La). E) Convex-upward hummocky cross-laminated sandstone beds (F3; member c; Phugtal). F) Hummocky cross-laminated sandstone intercalated with shelfal muds (F3/F4; member a; Phugtal).

Lithology.

The base of the Quartzite Series is sharp and characterized by the sudden increase of fine-grained siliciclastic detritus (Fig. 6A, B). The boundary with the underlying Zozar Fm. is more gradual in the Phugtal area, where it is marked by 10 m of calcareous arenites and marly limestones.

Four main lithofacies associations have been recognized within the unit, from bottom to top:

1) the basal interval is characterized by lenticular biocalcarenites with ooids, brachiopods and colonial corals (lithofacies A1, A3, A5). Lithoclastic calcirudites with up to decimetric fragments of coral colonies or reworked phosphatic nodules occur (A4, C2).

2) Well-bedded, dark greenish-grey and very fine-grained bioturbated arkoses (F3), intercalated with micaceous pelites, intra-bioclastic calcarenites and calcirudites (F4, A4), pass upward to coarser subarkoses and white cross-bedded supermature quartzarenites (F1) (Fig. 6C, D). Shallowing-upward cycles are capped by 50-60 cm thick biocalciruditic beds (A4), followed by black microruditic ironstones (G1) and by finer-grained ferruginous pelites (G2).

3) Grey micaceous siltstones (F4) are associated with burrowed micritic limestones (D1) and with very fine-grained bioclastic or quartzose arenites often displaying hummocky cross-lamination (A3, A5) (Fig. 6E, F).

4) Grey and fine-grained quartzose calcarenites (bioclastic or oolitic packstone/grainstone) yielding benthic foraminifera, brachiopods, crinoids, bryozoans and pelecypods (A3, A5, B1) are interbedded with dark micritic limestones (D1) locally containing megalodontids, with well-sorted or bioturbated quartzarenites, arkoses and subarkoses (F1, F3) (Fig. 7A) and with fine-grained bioclastic quartzose arenites (F2).

The transition to the Kioto Group is marked by the increasing abundance of thick-bedded dolomitic megalodontid limestones (B2) interbedded with orange-weathering quartzose sandstones with dolomitic intraclasts (F2a).

The Quartzite Series may be subdivided into three members:

The *lower member* (a), 54 to 97 m thick, comprises lithofacies associations 1 and 2. Two major coarsening-upward cycles represented by calcareous muds and immature sands (A3, A5, F3, F4) passing to clean quartz sands (F1) are capped by ironstone beds in the central part and at the top of the member. These intervals represent laterally continuous marker horizons, recognized in all stratigraphic sections. We recognized one oolitic ironstone interval also in the Zumlung gorge section (Zumlung Unit), which was ascribed to the base of the Tagling by Baud et al. (1982, fig. 9b). Chamosite-goethite ooids are generally concentrated in the lower 2 - 3 metres (G1) (Fig. 7B), but ferruginous material is scattered for up to 10 m in the overlying layers (G2). For detailed description and interpretation of ironstone intervals the reader is referred to Garzanti et al. (1989).

The *middle member* (b), about 50 to 100 m thick (precise measurement is often hampered by minor folding and faulting), corresponds to lithofacies association 3. Thick grey pelites (F4) containing ammonites in the Tongde La-Phugtal area (F4a) are associated with burrowed micritic limestones and thin-bedded immature arenites (A3, A5, D1). A 2 ÷ 3 m thick coral patch-reef (C1) was found in this interval at Zangla.

The *upper member* (c), 43 to 70 m thick, corresponds to lithofacies association 4. The member is characterized by the occurrence of shallowing-upward cycles represented by micritic limestones and hummocky cross-laminated bioclastic or quartzose arenites (A3, A5, D1, F3), passing to well sorted and up to fine-grained quartzose or oolitic sands with bipolar cross-lamination (F1, B1).

According to Fuchs (1987), only member (c) would correspond to the "Quartzite Series" of Hayden (1904). If the coral patch reef found in the lower part of member (b) at Zangla is equated with the "Coral Limestone" of Spiti (Bhargava & Bassi, 1985), then member (a) and the upper part of member (b) could be correlated respectively with the "Juvavites Beds" and "Monotis Shales".

Paleontological content and biostratigraphy.

The calcarenite layers of the Quartzite Series contain rich and well diversified faunal and floral assemblages. Echinoderm and brachiopod fragments are very abundant, whereas small pelecypods and gastropods are subordinate.

The base of member (a) in the Zangla-Namche La section (Tab. 2) contains a rich brachiopod association [*Fissirhynchia fissicostata* (Suess) and *Rhaetina* sp.], while large megalodontids are sporadically present in the upper member (c). Benthic foraminifera are widespread throughout the unit (Pl. 38). [*Aulotortus communis* (Kristan, 1957), *A. friedli* (Kristan-Tollmann, 1962), *A. sinuosus* Weynschenk, 1956, rare *Auloconus permodiscoides* (Oberhauser, 1964), rare *Agathammina* cf. *passerii* Ciarapica & Zaninetti, 1984, *Ophthalmidium* sp., *Glomospirella* sp.]. Two specimens of *Triasina* sp. possibly belonging to *Triasina hantkeni* Majzon, 1954, were found in member (c) in the Zangla section (Pl. 39, fig. 5).

Udoteacean algal remains (new form very close to *Halymeda*) are fairly abundant, particularly in the Zangla-Zozar area. Rare solenoporacean algae (*Solenopora* sp.) (Pl. 39, fig. 3), observed only in the Tanze section, are very similar to specimens found in the Zozar Formation (Jinshen section).

Bryozoan fragments (*Zozariella stellata* Schäfer & Fois, 1987, and *Dyscritella rhomboporata* Schäfer & Fois, 1987) are very rare and present only at the base of the lower member (a) in the Zangla-Namche La and Tanze sections.

Fragments of thamnasterioid corals (*Astraeomorpha crassisepta* Reuss, 1854), are abundant in the lower member (a) at Zangla (Pl. 39, fig. 2), where some specimens of *Montlivaltia* sp. are also present. Rare *Myriophyllia*-like colonies and large colonies (0.5-1 m in size) of "*Thecosmilia*" sp., locally forming patch-reef intervals, are scattered throughout the sequence. Spongiomorphid hydrozoans are very rare (Zangla-Namche La section).

In the Phugtal area, ammonites are fairly common, and a specimen of the *Juvavites* group of Norian age was collected east of Tongde La. All faunal assemblages are of Norian-Rhaetian affinity, and the available paleontological evidence and stratigraphic position suggest a Norian age for the Quartzite Series. The occurrence of *Triasina hantkeni* (Pl. 39, fig. 5) would indicate that the Norian/Rhaetian boundary is contained within the upper part of the unit.

Sandstone petrography.

Texture.

Average grain size mostly ranges from silt to fine sand (quartz grains reach at most granule size; Tab. 3). Sorting and roundness increase from moderately sorted and subangular very fine sandstones to well sorted and subrounded upper fine sandstones. The coarser samples are generally poorly sorted. The grain size distribution tends to be fine skewed and leptokurtic, and burrowed very fine-grained sandstones are strongly fine skewed.

QUARTZITE SERIES	Average Size	Longest Axis	Sorting	Skewness	Kurtosis	Maturity	Bioturbation
RINGDOM N=10 Mode	4÷2.5 Φ	2÷0.5 Φ	0.6÷0.9 σ Φ	+	+	Imm-Pwsh	Common
Range	up to 170 µm	Q up to 900 µm	0.6÷1.0 σ Φ	++to 0	+ to –	Imm-Pwsh	up to Intense
ZANGLA N=21 Mode	4÷2 Φ	2÷0 Φ	0.5÷0.8 σ Φ	+	+	Imm-Sub	Minor
Range	up to 450 µm	L--> 8 mm Q--> 2 mm	0.4÷2.0 σ Φ	++to–	+ to –	Imm-SMat	up to Intense
ZOZAR N=27 Mode	4÷2 Φ	2÷0 Φ	0.5÷0.8 σ Φ	+	+	Imm-Sub	Common
Range	up to 500 µm	L--> 24 mm Q--> 3 mm	0.5÷2.0 σ Φ	++to 0	++to–	Imm-SMat	up to Intense
PHUGTAL N=12 Mode	4÷2.5 Φ	2÷0 Φ	0.6÷1.5 σ Φ	+	0	Imm-Sub	Common
Range	up to 180 µm	L-->15 mm Q--> 1.2 mm	0.5÷3.0 σ Φ	++to–	++to–	Wck-Sub	up to Intense
N= 4 Mode LITHOZONE h (Kioto Group)	3 Φ	1.5 Φ	0.5 σ Φ	0	–	Pwsh	Very minor
Range	up to 140 µm	Q up to 430 mm	0.5÷0.7 σ Φ	0 to –	0 to –	Pwsh-Mat	

Tab 3 - Textural features of the Quartzite Series and uppermost Kioto Group (lithozone h) arenites (Zangla Unit). Values given for the Ringdom samples are only indicative due to recrystallization at low greenschist facies. Roundness is difficult to assess due to widespread syntaxial cementation. Textural parameters were estimated semiquantitatively and subsequently checked with point- counting techniques (Garzanti, 1986). Q = quartz; L = lithoclasts; Wcq = "wacke"; Imm = immature; Pwsh = poorly washed; Sub = submature; Mat = mature; SMat = supermature; + = fine skewed/leptokurtic; + + = very fine skewed/very leptokurtic; O = symmetrical/mesokurtic; - =coarse skewed/platykurtic.

Mineralogy.

The Quartzite Series mostly consist of subarkoses and arkoses, with detrital modes ranging from Q = 53, F = 46, L = 1 to Q = 100, F = 0, L = 0 (Tab. 4; for further information see Garzanti, 1986). The quartz/feldspar ratio is strongly controlled by grain size (r = +.60; 0.1% sign. level), and virtually all very fine grained sandstones are arkoses, whereas most fine sandstones are subarkoses. Quartzarenites with nearly exclusive monocrystalline quartz are invariably close or over 250 µm. Polycrystalline quartz is always rare.

Among detrital feldspars, kaolinized orthoclase and commonly fresh microcline (20% of total feldspars) prevail over frequently sericitized and mainly untwinned plagioclase (P/F ratio over 30% only in strongly albitized samples).

Granitoid, volcanic (durable felsitic types; Cameron & Blatt, 1971) and possibly phyllitic rock fragments are rare, whereas bimodally rounded ultrastable heavy minerals and white micas (up to 2.5% in very fine grained samples) were commonly recorded. Sandstones do not contain calcareous allochems, while extraclasts often occur in bio-calcarenites and oolitic ironstones. Up to medium-grained and poorly sorted quartzose

QUARTZITE SERIES		Grain Size	Q	F	L	Qm	P	K	C/Q	P/F	Or/F	Mi/F	CA/F	NCE	CI	CEM	MAT	AUT
N = 5 ZANGLA	Mean	250	83	17	0	83	2	15	1	12	63	24	1	67	0	22	4	7
pts. 1400	Range	120 ÷ 450	58 ÷ 100	0 ÷ 42	0	58 ÷ 100	0 ÷ 6	0 ÷ 39	0 ÷ 1	7 ÷ 16	48 ÷ 83	9 ÷ 39	0 ÷ 3	60 ÷ 73	0	10 ÷ 32	≤ 8	≤ 28
N = 11 ZOZAR	Mean	165	83	17	0	84	5	11	1	30	51	18	1	64	1	11	16	7
pts. 4140	Range	80 ÷ 370	53 ÷ 100	0 ÷ 46	0 ÷ 1	54 ÷ 100	0 ÷ 15	0 ÷ 31	0 ÷ 2	15 ÷ 71	10 ÷ 75	5 ÷ 46	0 ÷ 14	55 ÷ 76	0 ÷ 16	3 ÷ 25	≤ 38	≤ 31
N = 5 PHUGTAL	Mean	120	81	19	0	81	6	13	0	26	56	16	2	60	0	9	24	7
pts. 1305	Range	75 ÷ 180	71 ÷ 85	15 ÷ 29	0	71 ÷ 86	2 ÷ 14	8 ÷ 19	0 ÷ 1	11 ÷ 50	33 ÷ 78	11 ÷ 22	0 ÷ 6	56 ÷ 64	0	0 ÷ 23	≤ 40	≤ 16
N = 4 LITHOZONE h	Mean	120	99	1	0	99	0	1	1	0	tr.	0	0	32	14	2	1	52
pts. 1006	Range	100 ÷ 140	97 ÷ 100	0 ÷ 1	0 ÷ 1	99 ÷ 100	0	0 ÷ 1	0 ÷ 2	0		0	0	30 ÷ 35	5 ÷ 19	0 ÷ 4	0 ÷ 1	45 ÷ 56

Tab 4 - Petrography of the Quartzite Series and uppermost Kioto Group (lithozone h) arenites (Zangla Unit). All values given in percent. Q = quartz (Qm = monocrystalline; C = composite); F = feldspars (P = plagioclase; K = K-feldspar; Or = orthoclase and other untwinned K-spars; Mi = cross-hatched microcline; CA = chessboard-albite); L = lithic grains; NCE = non-carbonate extraclasts; CI = carbonate intraclasts; CEM = cement; MAT = "matrix"; AUT = authigenic minerals; parameters after Dickinson (1970), Dickinson & Suczek (1979) and Zuffa (1980).

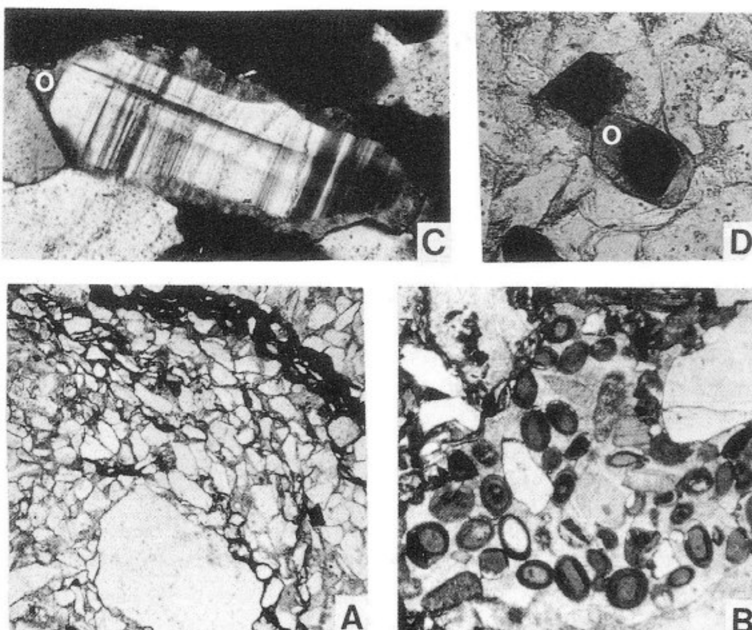


Fig. 7 - Petrography of the Quartzite Series. A) Poorly sorted bioturbated fine grained sandstone (F1; member c, Zozar, 32 X). B) Chamosite ooids in bimodally sorted bioclastic ironstone (G1; ironstone I, member a, Zangla, 20 X). C) Diagenetic kaolinization of K-feldspar cement (o) grown over fresh detrital microcline (F3; member c, Zozar, crossed polars, 130 X). D) Large abraded tourmaline overgrowth (o) (F1; member a, Zozar, 130 X).

arenites or "wackes" with subrounded quartz grains and commonly oversized and squashed dolomitic intraclasts represent a distinct petrographic marker recognized at the base of the Kioto Group all along the Zanskar mountains (Fig. 10D).

Diagenesis.

Cements commonly range 25% to 35% in non-bioturbated sandstones and less than 10% in highly burrowed samples. Cementation thus occurred prior to significant compaction and was probably completed in the early stages of diagenesis (within 1 km of burial and a few tens of My at most; Blatt, 1979; Dutta & Suttner, 1986). Relative abundances of authigenic minerals are strongly controlled by detrital mineralogy (arkosic sandstones are richer in feldspar overgrowths and hybrid arenites are calcite-cemented).

Sericitic patches (up to 8% in some very fine-grained sandstones) and recrystallized phyllosilicates (which may reach up to 40% in intensely bioturbated samples), may partly represent diagenetic replacements of feldspar grains, as suggested by positive correlation between phyllosilicate abundance and quartz/feldspar ratio in very fine-grained samples ($r = + 0.67$; 5% sign. level).

Feldspar grains have locally undergone significant albitization, testified by anomalous P/F ratio (up to 71%) and abundant chessboard albite (CA/F up to 14%) in some samples. Kaolinization of K-feldspars also took place during diagenesis, as it affected both K-spar grains and authigenic overgrowths (Fig. 7C). Late diagenetic minerals include widespread calcite, dolomite, siderite and titanium oxides.

Quartz recrystallization textures and the growth of stilpnomelane, muscovite or even biotite during the Tertiary Himalayan deformation point to anchimetamorphic temperatures around 300°C in most of the lower Zangla Unit and even lower greenschist facies conditions in the Ringdom and Sarchu areas (Garzanti & Brignoli, 1989).

Depositional environment.

The Quartzite Series record a prominent terrigenous event in the young Indian passive margin.

The lower member (a) is characterized by deposition of terrigenous to calcareous arenites in storm-controlled shallow-marine environments, as testified by widespread hummocky cross-lamination. Major shallowing-upward sequences are 20 to 50 m thick and begin with very fine grained, moderately sorted arkoses rich in silt and micas, showing ripple marks or bioturbation. These sediments were probably deposited in lower shoreface environments, close or below fair-weather wave-base. They are followed by quartz-rich coarser sandstones with high-angle tangential cross-lamination, pointing to a high-energy upper shoreface and possibly even aeolian backshore depositional environments.

These intervals, up to 10 m thick and characterized by better sorted and coarser sandstones, show both shore-normal (NNE-ward) and shore-parallel bipolar (WNW to ESE) paleocurrent directions, suggesting action of both longshore and tidal currents as sand-transporting agents. Subordinate tidal action is also testified by the local occurrence of herringbone structures. The lower member of the unit may thus represent a medium-energy mesotidal shoreline complex (McCubbin, 1982; Walker, 1984).

In the more distal Phugtal area, the finer grain size and the abundance of hummocky lamination testify to storm deposition mostly between fair-weather and storm wave-base.

The microruditic layers rich in iron oolites found at the top of shoaling sequences testify to low sedimentation rates and reworking of older littoral deposits (as suggested by the occurrence of arenitic pebbles) during rapid sea-level rise.

The middle member (b) is characterized by widespread deposition of calcareous to terrigenous muds in quieter and deeper waters. Water depth was shallow enough to allow growth of patch reefs, as testified in the Zangla area, and possibly even shallower at Ringdom, where pelitic intervals are poorly developed. Greater paleodepth in the Tongde La-Phugtal area is indicated by the abundance of offshore pelites containing sparse ammonoids. All available evidence thus indicates deposition on a continental shelf gradually deepening toward the present north east.

The upper member (c) is characterized by biomicrites and micaceous siltstones, gradually passing upward to biocalcarenites and clean beach sands. At the base of the Kioto Group, shallow subtidal megalodontid limestones intercalated with texturally inverted (Folk, 1980, p.104) arenites with dolomite intraclasts testify to mixed siliciclastic-carbonate sedimentation in shallow transgressing seas.

Sea-level changes and sequence stratigraphy.

The sharp base of the Quartzite Series represents a transgressive surface, onlapped by graded calcirudites with coral-bearing lithoclasts or by arenites with reworked phosphatic nodules. The occurrence of phosphates and lithoclasts may be explained with starvation during rapid sea-level rise and subsequent reworking by storm waves during rapid transgression, to form coarse "rubble zones" (Harris et al., 1986).

Next, shoaling sequences show an overall increase in grain size of coarser beds from very fine to medium sand. Sediment supply was thus sufficient to compensate for relative sea-level rise, and the shoreline was stationary or even moving seaward during deposition of the lower member.

The sequence is then punctuated by two major and possibly two or three minor ironstone intervals, separating times of aggradation and prograding shoreline and testifying to ravinement and shoreline retreat as a response to transgressive pulses in a period of rapid eustatic rise ("Transgressive system tract" of Haq et al., 1987).

After the flooding event marked by the upper ironstone, widespread deposition of offshore muds testifies that maximum depth was reached in the middle member (b) (earlier in the proximal Zangla-Zozar area and later in the distal Tongde La-Phugtal area, where ammonoids are found up to the upper part of the middle member).

The regressive sequence ("Highstand system tract" of Haq et al., 1987), continuing in the upper member (c), is capped by peritidal carbonate to foreshore terrigenous arenites. The texturally inverted sandstones with reworked dolomite intraclasts recognized in all sections may testify to ravinement of underlying sands and dolomite muds during renewed transgression just above the base of the Kioto Group.

Sedimentation rates around 20 m/My can be inferred by correlation with the Norian global depositional sequence (Cycle UAA-4; Haq et al., 1988), which unfortunately is highly tentative, due to scarcity of biostratigraphic data and poor definition of the Triassic eustatic curves. The Norian sequence, in fact, is drawn very differently in successive versions of the Haq et al. curve, and no major condensed section is reported in the Late Triassic.

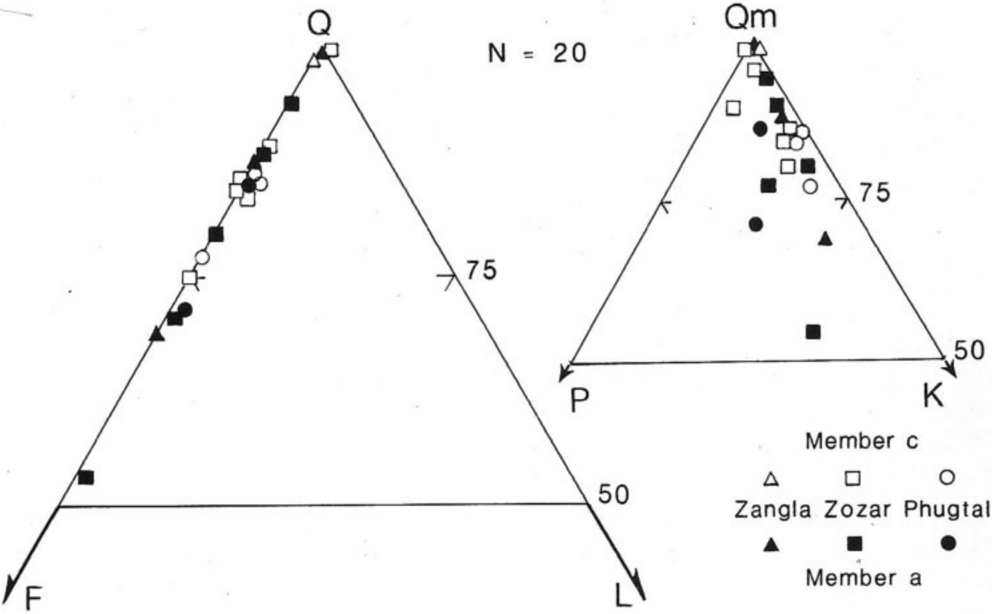


Fig. 8 - Standard QFL and QmPK plots (Dickinson & Suczek, 1979) show that the Quartzite Series is made of quartzo-feldspathic detritus shed from the Indian continental block. K pole includes all alkali feldspars (orthoclase, microcline and chessboard albite). Note that member (a) sandstones (full symbols) tend to be richer in feldspars than member (c) samples (open symbols). Average grain size of counted samples is around 175 μm for both members.

Provenance.

The petrographic composition of the Quartzite Series indicates a "continental block, craton interior" provenance (Fig. 8; Dickinson & Suczek, 1979). Detritus was derived from erosion of the southern Indian craton in the south, formed by microcline-bearing granitoids, gneisses, tourmaline-bearing pegmatites and felsic volcanics (Gansser, 1964, pp. 10-20), and blanketed by Late Precambrian sandstones notably rich in detrital and authigenic tourmaline (Gokhale & Bagchi, 1959; Awasthi, 1961; Lahiri, 1964; Rajulu & Nagaraja, 1969).

Detritus was carried to the Tethyan margin by northward-flowing river systems. During transport and reworking in shallow-marine environments, destruction of less stable and durable grains took place, with enrichment of monocrystalline quartz, microcline and ultrastable heavy minerals (Blatt, 1967; Mack, 1978). Also, polycyclic detritus was probably mixed with first-cycle sediment, as indicated by the low C/Q ratio even of medium-grained sandstones (Mack, 1981), by the bimodal roundness of ultrastable heavy minerals and by the occurrence of tourmaline grains with beautiful abraded overgrowths (Fig. 7D; Zuffa, 1987).

Sources for polycyclic grains may have been Late Proterozoic clastics deformed during the Cambro-Ordovician Orogeny (Jain et al., 1980; Garzanti et al., 1986), Carboniferous Gondwana tillites and exposed Permo-Triassic coastal plain sediments.

Concentration of feldspars in the very fine-grained fraction, a typical feature of arkose-quartzarenite sandstone suites deposited in high-energy environments (Odom et al., 1976), is ascribed to breakage along twin or cleavage planes during transport and reworking processes. The abundance of feldspars with respect to detritus provided by foreland blocks in equatorial climate (Potter, 1978; Franzinelli & Potter, 1983; Johnsson et al., 1988) and their slight alteration prior to deposition suggest that chemical weathering in the drainage basin was not very effective. Climate was thus probably semiarid, at least for the lower part of the unit. The gradual decrease in feldspars towards the top of the Quartzite Series might suggest longer residence time of detritus on alluvial plains and paralic environments or increasingly warm and humid conditions towards the end of the Triassic, when the Indian passive margin lay at a latitude of 35-40° S (Suttner & Dutta, 1986).

Alternatively, abundance of feldspars may be ascribed to rejuvenation of the Indian foreland, causing sudden erosion and rapid transport of detritus to the Tethyan shores. This hypothesis is supported by the evidence of Late Triassic rift volcanism in the remnants of the more distal Zanskar margin now exposed in the Mélange zone underlying the Spongtang Ophiolite (Reuber et al., 1987).

Kioto Group.

The Para and Tagling units were firstly described by Stoliczka (1866). Next, Hayden (1908) proposed the name Kioto Limestone for the whole sequence in the Spiti area. More recently, the Kioto Limestone of the northern Zanskar units has been described by Baud et al. (1982), who consider the Kioto succession as a group divided in two formations (Para and Tagling). The most striking feature of these two units is the abundance of megalodontids and *Lithiotis* respectively.

The Kioto Limestone of southern Zanskar was described by Raina and Bhattacharyya (1977) who named it Megalodon Limestone. The anomalous thickness (1500 m) of the sequence and the repetition of lithozones suggest a tectonic doubling. The name Simokhambda Formation recently proposed by Srikantia (1981) is considered as a junior synonym of the Kioto Group.

The unit overlies the Quartzite Series from Ringdom Gompa to the Tanze area. Six stratigraphic sections have been measured in this area, two of which cover the whole unit (Tab. 5). In the Zangla Unit, the mainly Rhaetian Para Formation (lithozone a) is invariably present but with moderate thickness. The Liassic Tagling Formation (lithozones b to g) is predominant but does not contain the characteristic *Lithiotis* fauna. *Lithiotis* are present only in the Zumlung and Khurna nappes, cropping out to the northeast.

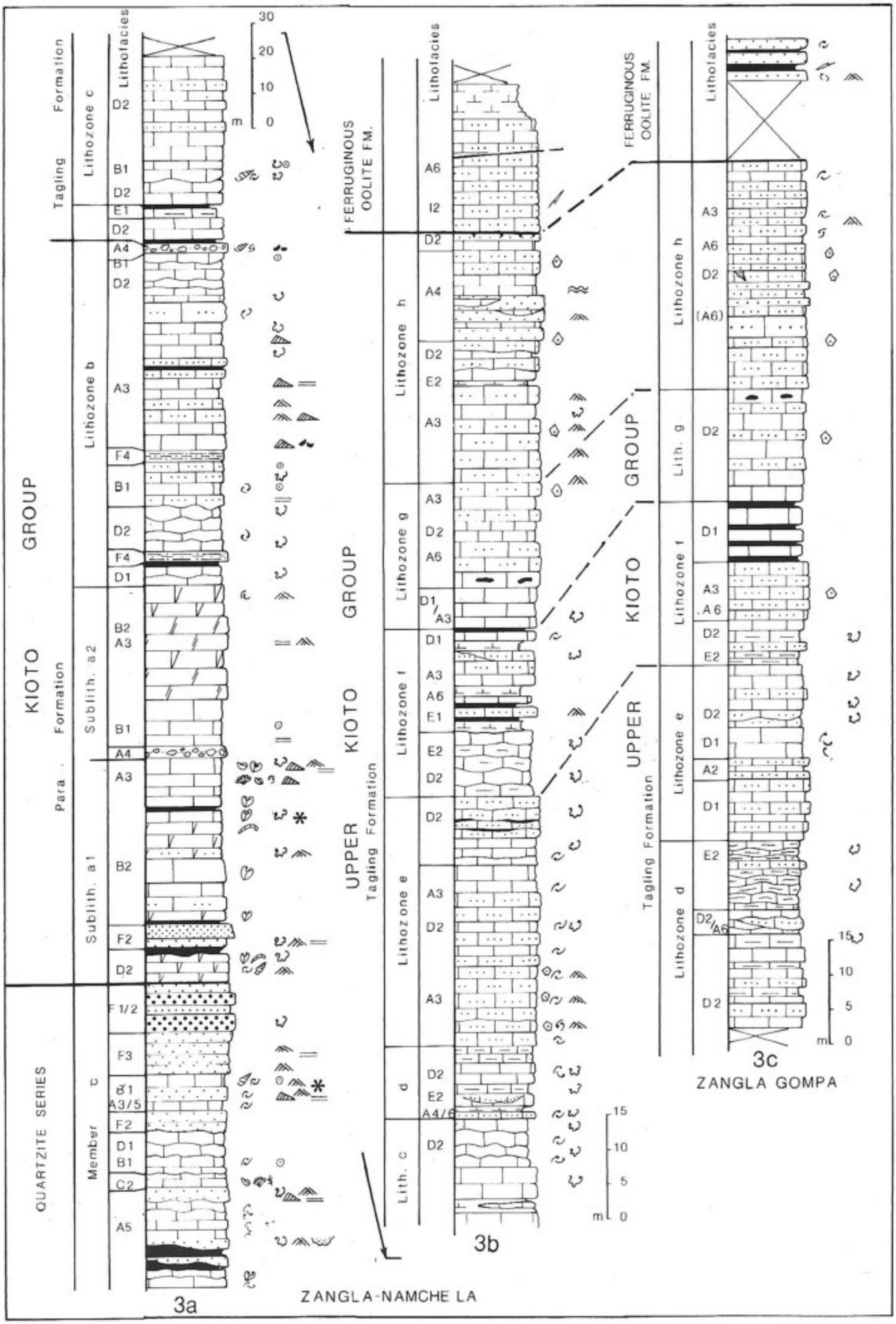


Fig. 9 - Stratigraphic columns and sedimentary structures for the Kioto Group (Ringdom-Spanboth, Zangla-Namche La, Zangla Gompa and Zozar sections; Zangla Unit).

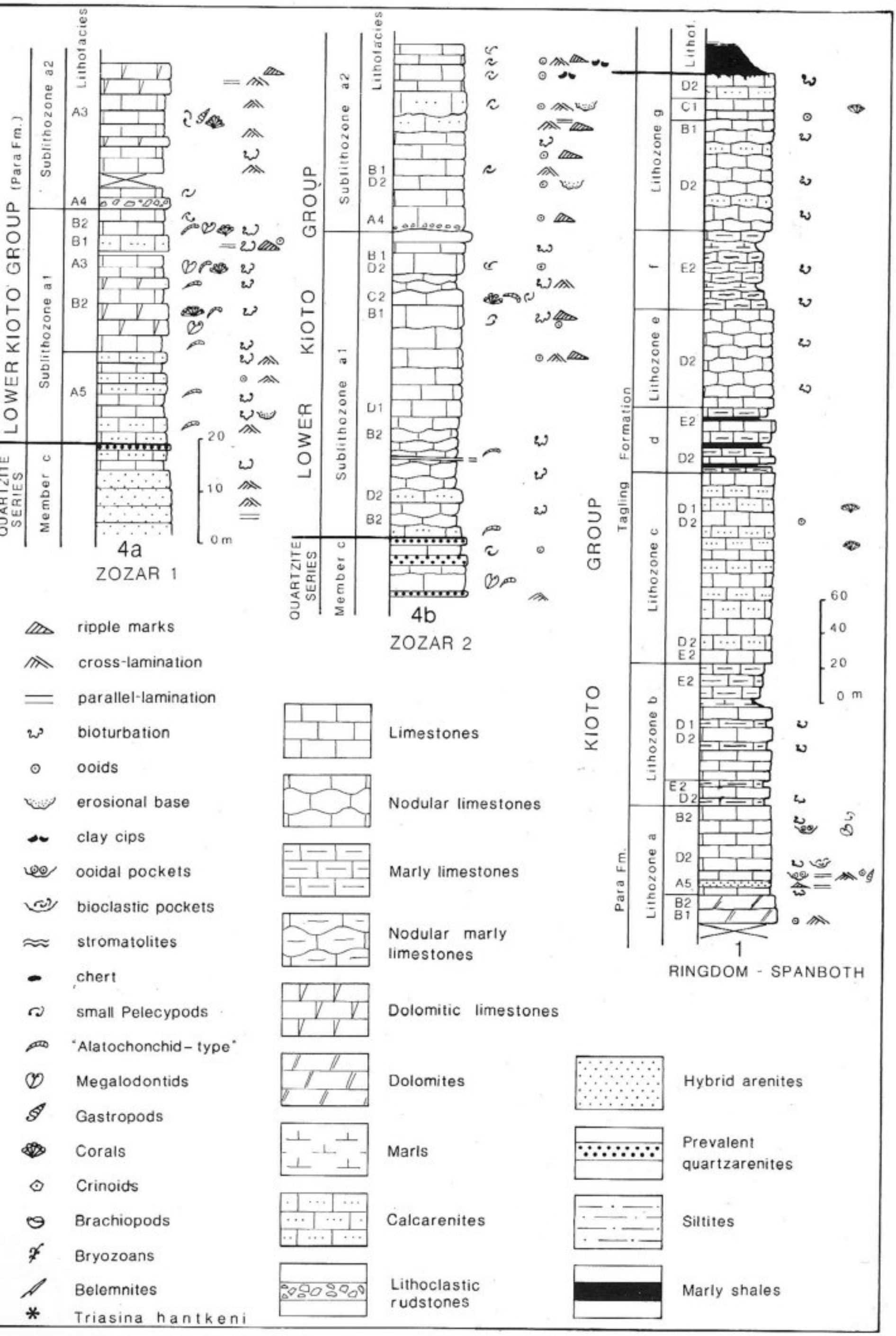

4a
ZOZAR 1
4b
ZOZAR 2
1
RINGDOM - SPANBOTH
LOWER KIOTO GROUP (Para Fm.)
LOWER KIOTO GROUP
KIOTO GROUP
Tagling Formation
Para Fm.
QUARTZITE SERIES
Member c
Sublithozone a1
Sublithozone a2
Lithofacies
Lithozone a
Lithozone b
Lithozone c
Lithozone e
Lithozone g
Lithof.
ripple marks
cross-lamination
parallel-lamination
bioturbation
ooids
erosional base
clay cips
ooidal pockets
bioclastic pockets
stromatolites
chert
small Pelecypods
"Alatochonchid-type"
Megalodontids
Gastropods
Corals
Crinoids
Brachiopods
Bryozoans
Belemnites
Triasina hantkeni
Limestones
Nodular limestones
Marly limestones
Nodular marly limestones
Dolomitic limestones
Dolomites
Marls
Calcarenites
Lithoclastic rudstones
Hybrid arenites
Prevalent quartzarenites
Siltites
Marly shales

Fig. 9b

Tab. 5 - Kioto Group stratigraphic sections.

LITHO FACIES	THICK. m	LITHOZONES	SEDIMENTARY STRUCTURES	MICROFACIES	FOSSILS
	(1)	**RINGDOM GOMPA - SPANBOTH CHU SECTION** (Complete Kioto Group, lower lithozone (a) not exposed).			
B1/B2 A5 D2/B2	67	a) Oolitic dolomites with rare sandy intercalations, passing upward to bio-intracalcarenites and dark grey calcilutites.	Bioturbation; parallel and cross-bedding; flaser to rare large scale cross-bedding at the base; storm layers; erosional base/ooid lenses, mud chips, Fe oxides. Bedding: 0.2-1 m.	a) Bioclastic, oolitic pack., rare grainstones, wackestones.	a) Small, large pelecypods (rare megalodontids), gastropods, crinoids. Rare oncoids.
D2/E2	85	b) Planar dark grey calcilutites and marly limestones.	Bioturbation. Bedding: 0.15-0.4 m.	b) Fine bioclastic pack., wack. mudstones, rare ooidal grainstones.	b) Rare coral fragments.
D2/D1 E2	110	c) Intraclastic, rarely bioclastic calcarenites. Rare ooids.	Bedding: 0.15-0.6 m.		
E2/D2	45	d) Thin-bedded dark marly calcilutites alternating with marls, calcarenites.	Rare bioturbation. Bedding: 0.05-0.2 m.		
D2/E2	100	e+f) Slightly nodular to planar dark grey calcilutites and marly limestones.	Bioturbation. Bedding: 0.06-0.35 m.		
D2/ B1/ C1/D2	90	g) Slightly nodular intraclastic rarely bioclastic calcarenites alternating with calcilutites.	Bioturbation; burrowing in the topmost layer. Bedding: 0.2-0.6 m.	g) Bio-intraclastic packstones, wackestones, mudstones.	g) Rare colonial corals, pelecypods. Pelagic pelecypods in the topmost layer.
Tot.	497				
	(2)	**OMA CHU SECTION** (Uppermost Kioto Group).			
A3/B1/E1	35	g) Planar dark grey fine calcarenites with ooids intercalated with fossiliferous marly limestones.	Ripple marks and megaripple cross-lamination in the calcarenites. Bioturbation in the marly limestones.	Bio-intraclastic, oolitic pack., fossiliferous wack., mudstones.	Echinoderms, benthic foraminifers (textulariids, fragments of *Haurania* sp., *Nautiloculina* sp.).
D2 A6	8	Thin-bedded, slightly nodular dark grey calcilutites and fine calcarenites, thin sandy layers.	Lenticular bedding, mud chips in the calcarenites; cross-lamination in the sandy layers.	Bio-intraclastic packstones, wackestones.	
	(3)	**ZANGLA-NAMCHE LA SECTION** (Two complete Kioto Group sections). Possibly 80-100 m have not been measured in the central part. Section I			
B2/ A3/A5/ D2 F2/F3 B2/A3 A4/B1	114	a) Fossiliferous planar to nodular, dolomitic calcilutites and biocalcarenites (a1) alternating with dark grey calcilutites and fine hybrid quartzarenites at the base. In the upper sublithozone (a2) basal ruditic layer, calcarenites, ooids.	Parallel and cross-bedding; bioturbation, mud chips, storm layers. Bedding: 0.3-1 m, amalgamated beds.	a) Bioclastic pack. with subordinate intraclasts and peloids.	a) Small and large pelecypods (megalodontids) similar to *Paramegalodus-Rhaetomegalodon*, "alatoconchid-type", brachiopods, rare corals ("*Thecosmilia*" sp.), echinoderms, gastropods; rare udoteacean algae (*Halymeda*-like form); benthic foraminifers: *Aulotortus communis, A. tumidus, Auloconus permodiscoides, Triasina hantkeni.*
A3/ D2/B1 (A4) (F4/E1)	108	b) Planar to nodular intraclastic calcarenites with rare ooids alternating with dark grey calcilutites. Rare sandy, silty and marly layers.	Parallel and cross-bedding; wave ripples, storm layers; mud chips; bioturbation. Bedding: 0.03-0.8 m.	b) Fine bioclastic packst. alternating with mudstones/bioclastic wackestones in the lower part; prevailing oolitic/bioclastic grainstones upwards.	b) Echinoderms, small pelecypods, gastropods, benthic foraminifers (*Glomospira* sp., *Endothyra* sp., *Trochammina* sp., *Valvulinids*), very rare corals.
D2	45	c) Planar dark calcilutites and subordinate fine intra-bioclastic calcarenites and oolitic limestones.	Rare bioturbation. Bedding: 0.07-0.6 m.	c) Mudstones/bioclastic wackestones and oolitic-bioclastic grainst./packstones. Diffuse micritized ooids and aggregate grains. Locally abundant intraclasts partially lithified.	c) Gastropods (small nerineids), pelecypods, brachiopods, echinoderms, benthic foraminifers (*Endothyranella* sp., *Glomospirella* sp.), crinoids.
		Section II			
	14	c) As section I. (Possibly 80-100 m of section has not been measured). Section II is strongly recrystallized.			
D2/ E2/ (A6)	11	d) Dark grey planar to nodular calcilutites and marly limestones with rare intrabioclastic layers and pink brown quartzose calcarenites.	Bioturbation. Bedding: 0.02-0.2 m locally amalgamated.	d) Intra-bioclastic fine wackestones, mudstones, fine intrabioclastic packstones.	d) Crinoids, echinoids, small pelecypods, brachiopods, gastropods.
D1/D2 A3 (E2)	35	e) Dark grey calcilutites and thin intrabioclastic calcarenites. Rare marly limestones.	Storm layers; bioturbation. Bedding: 0.03-0.3 m.		
	24	f) Alternating dark grey calcilutites and shales.	Bioturbation. Bedding: 0.05-0.2 m.		
A3 (A6)	21	g) Fine calcarenites with thin quartzarenites-quartzose calcarenites.	Chert nodules.	g) Intrabioclastic packstones, wackestones.	g) Crinoids, rare pelecypods, brachiopods, gastropods.
D2 A3 (A6)	35	h) Very fine calcarenites; planar dark grey bioclastic calcarenites, rare calcilutites; sandy intercalations.	Bioturbation; low-angle cross-bedding, herringbones, storm layers, small sedimentary dikes. Bedding: 0.03-0.6 m, amalgamated.	h) Bioclastic and intrabioclastic packestones with quartz extraclasts.	h) Small pelecypods, crinoids, belemnite fragments at the top.
Tot.	407				

Tab. 5 - Kioto Group stratigraphic sections.

LITHO FACIES	THICK. m	LITHOZONES	SEDIMENTARY STRUCTURES	MICROFACIES	
	(3)	**ZANGLA GOMPA SECTION** (section III) (Upper Kioto Group).			
D2	14	c) Dark grey planar to nodular fine intrabioclastic calcarenites, intercalated with calcilutites.	Storm layers, bioturbation, burrowing. Bedding: 0.03-0.3 m.	c) Calcarenitic layers are pack./grainstones with bioclasts and intraclasts formed by fragments of mud-supported microfacies.	c) Small pelecypods, rare benthic foraminifers (textulariids, *Endothyranella* sp., valvulinids).
D1/ E2/(A6)	13	d) Planar dark grey calcilutites, intercalated with marly limestones; quartzose calcarenitic lenses.	Bioturbation. Bedding: 0.05-0.25 m.		d) Crinoids, small pelecypods.
A3/ D2	25	e) Dark, lenticular fine to coarse bioclastic calcarenites alternate with dark grey planar calcilutites.	Erosional base, normal grading high-angle cross laminat., ripple marks, bioturbation, storm layers, mud chips. Bedding: 0.01-0.5 m, amalgamated.	e) Calcarenites are bio-intraclastic packstones. Intraclasts formed by fragments of mud-supported microfacies.	e) Small pelecypods, gastropods, spongiomorphid hydrozoans, echinoderms.
E2/ A3/ D2	24	f) Alternation of dark grey marls and peloidal marly limestones with fine to coarse lenticular bioclastic calcarenites.	Bioturbation, normal grading, lenticular bedding, herringbones, channel-fill, mud chips. Bedding: 0.1-0.6 m, amalgamated.	f) Calcarenites are bio-intraclastic rudstones/grainstones.	f) Echinoderms, rare gastropods, rare hydrozoans (*Lamellata* cf. *wahneri*).
D2/	17	g) Dark grey planar calcarenites alternate with dark calcilutites with locally nodular chert.	Rare cross-bedding, bioturbation. Bedding: 0.3-1 m.	g) Calcarenites are grainst./packstones rich in ooids. Strong micritization. Rare bioclasts.	g) Very rare benthic foraminifers (*Endothyranella* sp., textulariids, valvulinids).
A3/ D2/ A6	33	h) Grey, fine to medium calcarenites and subordinate calcilutites. Brown, thin sandy intercalations. At the top coarse intrabioclastic calcarenites locally rich in Fe oxides.	Storm layers, herringbones, ripple marks, oblique and low-angle cross-laminations, bioturbation, burrowing in the topmost layers. Bedding: 0.2-0.6 m, amalgamated layers.	h) Calcarenites are grainst./packstones rich in intraclasts and peloids. Locally abundant ooids and grapestones. Rare bioclasts.	h) Rare pelecypods, gastropods, echinoderms, benthic foraminifers (*Tetrataxis* cf. *inflata*, *Haurania* sp., *Nautiloculina* sp.).
Tot.	126				
	(4)	**ZOZAR 1 SECTION** (Lower Kioto Group; bottom and top not exposed).			
A5/ B2/ (B1) F1/F3	11	a) Grey, planar, fine grained biocalcarenites and dolomitic limestones with whole fossils and ooids alternate with sandy and silty layers.	Bioturbation, load-casts; cross-bedding and lenticular bedding; low-angle cross-lamination, mud chips, erosional base. Bedding: 0.15-0.8 m, amalgamated layers.	a+b) Bioclastic grainst./packstones with subordinate ooids. Strong similarity with the calcarenitic layers of the Quartzite Series.	Echinoderms, diffuse udoteacean algae (*Halymeda*-like form), abundant benthic foraminifers (*Aulotortus sinuosus*, *A. communis*, *A. tenuis*, *A. tumidus*, rare *A.* cf. *friedli*. In the dolomitic limest.: megalodontids (*Paramegalodus-Rhaetomegalodon*), "alatochonchid-type".
B2/ D1/D2 (A5)	33	Planar to nodular dark grey calcilutites with whole fossils alternate in the lower part with quartzose calcarenites.	Bioturbation. Bedding: 0.3-0.8 m, amalgamated layers.		
B1/ D1/D2	63	Fine to coarse oo-biocalcarenites and subordinate planar to nodular dark calcilutites with whole fossils.	Large scale cross-bedding, ripple marks, erosional base, parallel lamination, wave ripples, mud chips; bioturbation in the calcilutites. Bedding: 0.05-0.6 m, amalgamated layers.	Bioclastic packstones and wackestones. In the upper part: dolomitized, oolitic grainstones.	Common udoteacean algae (*Halymeda*-like form), benthic foraminifers (abundant *Aulotortus sinuosus*, *A. communis*, rare *A. friedli*). Rare gastropods, small pelecypods ("alatochonchid-type"), rare corals (*Thecosmilia* sp.).
Tot.	107				
	(4)	**ZOZAR 2 SECTION** (Lowermost Kioto Group).			
A5/B2	16	a) At the base quartzose calcarenites.	Large scale cross-bedding, ripple marks, ooids, lenticular bedding, parallel lamination, erosional base, bioturbation, burrows, load casts, mud chips. Bedding: 0.05-0.8 m.		"alatochonchid-type" large pelecypods.
B2/ A3 (B1)	55	Grey planar bioclastic calcarenites and subordinate dark grey dolomitic calcilutites with whole fossils.			Small and large pelecypods (*Paramegalodus*, *Rhaetomegalodon*, "alatochonchid-type"), gastropods, crinoids.

In this paper we follow the Baud et al. (1982) Kioto lithostratigraphy also including at the top a transitional lithofacies (lithozone h) comparable to the Laptal Beds (Heim & Gansser, 1939). Moreover in the Zangla Unit the Para and Tagling formations are not well defined because their boundary is often transitional and not well recognizable. The reasons of this situation are the lack of visible vertical and lateral facies changes within reefal and marginal platform carbonates (cf. Stutz, 1988), and the scarcity of fossils in the Kioto Group.

In this study we propose a detailed local lithostratigraphy made of several informal lithozones and sublithozones (Tab. 6).

Lithology.

The boundary with the underlying Quartzite Series is transitional. Conventionally it is set at the base of a 17 to 35 m thick transitional zone, where large pelecypods (megalodontids and alatochonchid-type) become abundant and sandy horizons are less frequent. The unit is 480 - 550 m thick in the Zangla Unit, including up to 35 m of the Laptal-type lithofacies. Reduction in thickness might be ascribed to partial interfingering with member (c) of the Quartzite Series (Zangla-Namche La area) or to erosion or non-deposition at the top of the unit (locally the Laptal-type facies is missing).

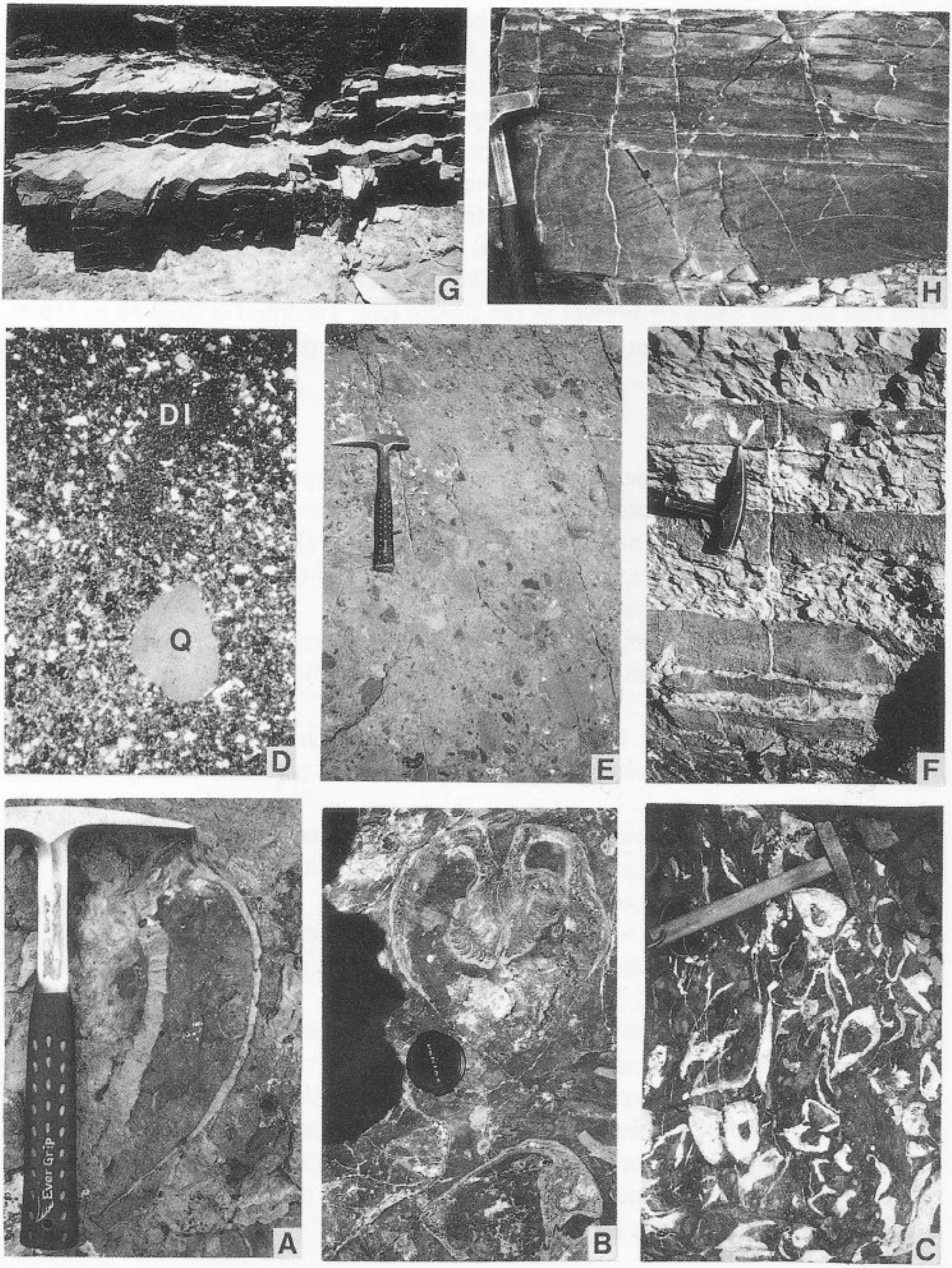
In the Kioto Group of the Zangla Unit, eight main lithozones have been recognized (Fig. 9). Only a few may be easily distinguished and have the character of distinct members. Nevertheless, these informal units have good lateral continuity and are useful for stratigraphic correlation within the Zangla Unit (Fig. 9).

Para Formation.

Lithozone a. The typical basal Kioto layers (sublithozone a1) are partially dolomitized and yield several large pelecypods (megalodontids, alatochonchid-type) (Fig. 10A,B,C). Bio-intraclastic packstones/rudstones (A3) with brachiopods, pelecypods, corals, benthic foraminifera and ooidal grainstones (B1) are intercalated with thick-bedded and intensely burrowed mudstones-wackestones with large pelecypods (B2). Locally 2-5 m thickening-upward sequences with basal pelites and oolitic calcarenites with gastropods and pelecypods (alatochonchid-type) are present, passing upward to cross-laminated oo-calcarenites capped by bioclastic beds (pelecypods, brachiopods). The upper part of the sequence is made by subtidal, fine to coarse calcarenites rich in megalodontids.

At the base, arkoses, fine hybrid quartzarenites, siltites and hybrid calcareous arenites (F2, F3, F4, A5) are still interbedded with bioclastic calcarenites, fossiliferous wackestones with reworked megalodontids and quartzose sandstones with dolomitic intraclasts (F2a) (Fig. 10D).

Fig. 10 - Typical biofacies and lithofacies of the Kioto Group. A) Large problematic pelecypod ("alatochonchid-type") (B2; sublithozone a1, Zozar). B) Large pelecypods (*Paramegalodus* group) (B2; sublithozone a1, Zozar). C) Whole and packed megalodontids (B2; sublithozone a1, Zangla-Namche La). D) Wacke with subrounded quartz grains (Q) and intrabasinal pseudomatrix formed by squashed oversized dolomite intraclasts (DI) (F2a; sublithozone a1, Zozar, crossed polars; 22 X). E) Upper bedding surface of lithoclastic rudstone (A4; boundary between sublithozone a1 and a2; Zangla-Namche La). F) Intrabioclastic calcarenites (A3) with scoured base and cross-lamination interbedded with bioturbated mudstones/wackestones (D1; lithozone g; Zangla Gompa). G) Symmetrical ripple marks in fine calcarenites (A3; lithozone b; Zangla-Namche La). H) High-angle cross-lamination and ripple marks in coarse calcarenites (A3) interbedded with bioturbated fine calcarenites and marly limestones (D2/E2; sublithozone A2, Zangla-Namche La).


G
H
DI
Q
D
E
F
A
Ever Grip
B
C

The upper part of the lithozone is generally less fossiliferous (a2 sublithozone) (Fig. 9) with two decimetric lithoclastic rudstones (Fig. 10E) at the base with micritic chips, rounded clasts and bioclasts (A4) and frequent storm layers. Thickness in the Zangla area reaches 114 m.

Lithozone b. Shallow-water intra-oo-bioclastic calcarenites (A3, B1) interbedded with dark nodular bioturbated biomicrites (D2). Close to the base, rippled (Fig. 10G) and high energy cross-laminated oo-biocalcarenites associated with thin siltites (F4) and ferruginous hybrid arenites (A5) occur. Frequent storm layers with bioclasts, intraclasts, micritic chips at the base and parallel lamination are also present. Thickening and coarsening-upward sequences (3-15 m) are characterized at the base by thin marly-silty layers, followed by dark nodular bioturbated micrites (D1) and then by grey bioclastic-intraclastic coarse calcarenites (A3). Thin dark pink calcarenites (A6) firstly appear. At the top of the lithozone chaotic coarse rudites (50 cm thick) with erosional base, decimetric clasts and micritic chips are present in the Zangla area. Thickness is from 85 to 110 m. This lithozone may represent a transitional unit between the Para and Tagling Formations.

Tagling Formation.

Lithozones c-g. The upper Kioto Group consists of sequences (10-20 m thick) made by two types of lithofacies associations. From the bottom to the top:

1) marly limestones, mudstones, marls (E2, E1, D2) often bioturbated and associated with storm deposits, calcarenitic lenses (A3) and centimetric pink-brown ferruginous quartzose calcarenites (A6) (lithozones d, f).

2) Coarse to fine bioclastic storm layers, mainly represented by crinoidal calcarenites (A3) associated with bioturbated biomicrites (D2); thickness from 25 to 40 m (lithozones e, g).

Cross-laminations are frequent at the base of each sequence. Bioturbation is frequent in lutites and fine calcarenites while it is absent in coarse calcarenites.

Lithozone (c) is made by prevalent calcilutites with fine calcarenitic intercalations. Shallow-water lithofacies with scattered ooids and local coral patch-reefs are present in the Zangla-Namche La and Ringdom Gompa sections (Fig. 9).

In lithozones (g,h) calcarenites prevail (A3, A6) (Fig. 10F). Lithozone (g) contains chert nodules (Zangla area), while westwards (Ringdom Gompa, Oma Chu areas) shallow-water facies (oolitic intercalations, megaripples, coral patch-reefs) are present (Fig. 10F).

Each lithozone may show a peculiar kind of high-frequency cyclicity:

1) mainly asymmetrical coarsening-upward cycles consist of basal marly limestones and marls (E2) followed by coarser intrabioclastic calcarenites (A3) and then by micrites (D1) with interbedded fine to medium calcarenites (D2). The upper part of the sequence consists of prevalent calcarenites (A3) often with ripples, cross lamination and thin intercalations of quartzose hybrid arenites. The most common lithofacies sequence is E (F4)→A3→D2/D1→A3. Each cycle is 3-15 m thick.

2) Symmetrical cycles mostly with lithofacies sequence E (F4)→A3→D2/D1→E.

3) In calcarenite-rich lithozones (g, h), fining-upward cycles are more evident: calcarenites (A3) with scoured base and rip-up clasts, often displaying graded-bedding pass upward to bioturbated fossiliferous (bivalves) micrites (D1) or interbedded micrites and fine bioturbated calcarenites (D2). Each cycle is 2.5-7m thick. Thickness of lithozone (c) is about 110 to 160 m, but precise measurement is prevented because of tectonic deformation. Lithozone (d) is about 13 m thick in the Zangla sections and 45 m in the Ringdom-Spanboth area. Lithozone (e) in the Zangla area is 25 to 35 m thick. Lithozones (f+g) are 41-45 m thick in the Zangla and Oma Chu areas, and reach more than 100 m in the Ringdom-Spanboth area.

Lithozone h. The uppermost lithozone is not always present, as in the Ringdom Gompa area. It is characterized by prevalent calcarenites (A3) alternating with micritic strongly bioturbated limestones (D2). Coarse calcarenites with cross-laminations are more frequent than in lithozone (g), and well sorted rusty quartzarenites or thin ferruginous calcarenites (A6) also occur. Toward the top belemnites become frequent in A6 lithofacies (Zangla Gompa section).

This lithozone, yielding an upper Lias-lower Dogger microfauna (Tab. 5), displays in the upper portion similarities with the Laptal Beds (Heim & Gansser, 1939; Baud et al., 1982). In this paper, lithozone (h) is considered as part of the Kioto Group because of its transitional boundary with the similar lithofacies of lithozone (g), the occurrence of still abundant micrites (D2), and its age, different from the Laptal Beds of Zumlung Unit ascribed to the upper Dogger (Jadoul et al., in prep.).

Lithozones (g) and (h) in the Zangla area may correspond in time with lithozone (g) in the Ringdom-Spanboth and Oma-Chu areas, as indicated by thickness considerations and foraminifera biostratigraphy (Tab. 5).

The top surface of the Kioto Group is often characterized by small borings and minor dolomitization. The boundary with the overlying Ferruginous Oolite Fm. is sharp and unconformable (Jadoul et al., 1985).

Lithostratigraphy, lithofacies distribution and microfacies of each measured section are synthesized in Tab. 5.

Paleontological content and biostratigraphy.

Sublithozone (a1) is characterized by the presence of large pelecypods [*Paramegalodus* sp., *Rheatomegalodon* sp. (Fig. 10B), "*alatoconchid*-type" (Fig. 10A)]. Small pelecypods, echinoderms, gastropods, brachiopods are always present and concentrated in the coarser layers. Corals ("*Thecosmilia*" sp.) occur in lithozone (a) and lithozone (g) of the Ringdom-Spanboth section. Hydrozoans (spongiomorphids, *Lamellata* cf. *wahneri* Flügel & Sy, 1959) are rare, and occur particularly in the Zangla Gompa section (lithozones e, f; Tab. 5).

Benthic Foraminifera form two different assemblages (Pl. 39, 40):

1) *Aulotortus communis* (Kristan, 1957), *A. tumidus* (Kristan-Tollmann, 1964), *A. tenuis* (Kristan, 1957), *A. sinuosus* Weynschenk, 1956, rare *A. friedli* (Kristan-Tollmann,

1962), *Auloconus permodiscoides* Oberhauser, 1964, *Triasina hantkeni* Majzon, 1954 (Pl. 40, fig. 1) (found only in lithozone (a) of the Zangla-Namche La section) characterize the high-energy grain-supported microfacies of sublithozone (a1).

Udoteacean algae remains (*Halymeda*-like form) (Pl. 40, fig. 8) are fairly abundant in samples containing foraminiferal assemblage 1.

2) *Glomospira* sp., *Glomospirella* sp., *Trochammina* sp., *Endothyra* sp., *Endothyranella* sp., *Tetraxis* cf. *inflata* Kristan, 1957, textulariids and valvulinids occur in fine packstones intercalated with the dark grey bioturbated calcilutites of lithozones (b, c, d, h). In lithozones (g, h) few specimens of *Haurania* sp. (Pl. 40, fig. 4) and *Nautiloculina* sp. have been found (Oma-Chu, Zangla Gompa).

The fauna and flora scattered in the whole Kioto sequences point to a Rhaetian - Liassic age (Zaninetti, 1976; Gazdzicki, 1974, 1983; Gazdzicki et al., 1979; Flügel, 1981). A more precise age can be ascribed to each lithozone from the occurrence of a few age-diagnostic forms. A Rhaetian age is inferred for sublithozone (a1) from the occurrence of *Triasina hantkeni* Majzon, 1954 (Zaninetti, 1976; Gazdzicki, 1974, 1983; Flügel, 1981) and megalodontids of the *Paramegalodus-Rhaetomegalodon* group (Allasinaz & Zardini, 1978) in the Zangla-Zozar area. The presence of rare Jurassic gastropods (nerineids) in the lowermost lithozone (c) suggests that the Rhaetian-Liassic boundary could occur within lithozone (a) or lithozone (b).

Tentative correlation with the global eustatic chart along with thickness and cyclicity analysis seem to restrict the Triassic-Liassic boundary within lithozone (a) and possibly at the base of sublithozone (a2). In the uppermost Kioto (lithozones g, h) the presence of benthic foraminifera (*Haurania* sp., *Nautiloculina* sp.) (Oma Chu-Zangla Gompa sections) suggests a late Liassic - ? early Dogger age. Consequently, a Liassic age is inferred for lithozones (c,d,e, f, g) and probably (b), for a total thickness of about 400 m.

Possibly the upper part of member c of the Quartzite Series and sublithozone (a1) of the Kioto Group can be ascribed to the Rhaetian, for a maximum thickness of about 100-120 m.

Petrography and provenance of uppermost Kioto arenites.

The uppermost Kioto (lithozone h) hybrid arenites are upper very fine to lower fine-grained, with longest axis in the medium sand range. Samples are well to moderately-well sorted, poorly washed to mature, subangular, near symmetrical to coarse skewed and platykurtic (Tab. 3). Burrowing is absent.

All of the counted samples are peloidal quartzarenites cemented by blocky calcite, with average composition Q = 99 F = 0.7 L = 0.3. Siliciclastic extrabasinal detritus consists of nearly exclusive monocrystalline quartz, with rare feldspars, resistant felsitic volcanic rock fragments and ultrastable heavy mineral fraction. Carbonate allochems are invariably abundant and mostly consist of recrystallized peloids with a few recognizable echinoid plates.

These hybrid quartzarenites are passive margin sands ultimately derived from the Indian Craton. Higher quartz content relative to the Quartzite Series may be ascribed to more humid climate in the Early Jurassic or possibly to higher residence time of detrital grains in the coastal plains. Increasing stability may have also resulted from extensive reworking by marine currents, which effectively mixed terrigenous detritus and carbonate allochems in a shallow-water shelf.

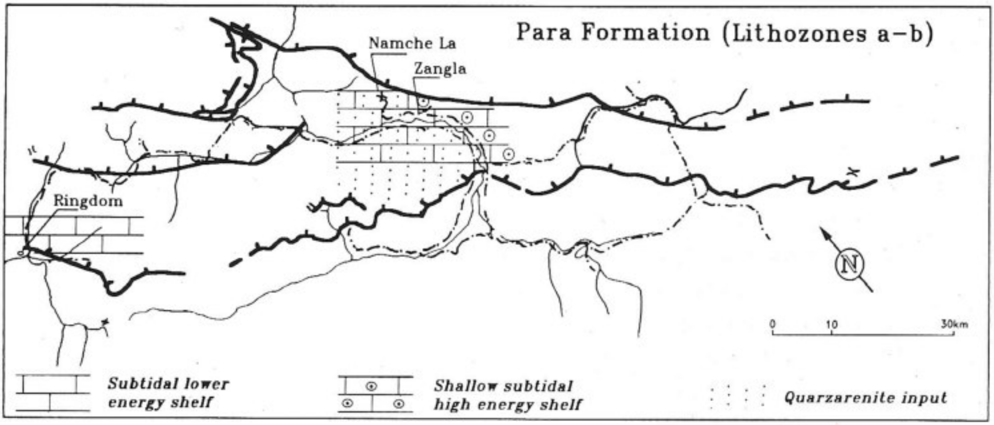


Fig. 11 - Palaeogeographic sketch for the Para Formation (lithozones a and b; lower Kioto Group).

Depositional environment.

The Kioto Group represents a transgressive-regressive megasequence, mostly developed in inner shelf storm-dominated environments (cf. Aigner, 1985).

The lower part of the Para Fm. (lithozone a) was deposited in a shallow subtidal restricted to high-energy shelf (Fig. 11). In the Zangla area, episodic fine terrigenous supply in sublithozone (a1) suggests the existence of a still active tidal delta complex. Lithozone (a) in the Zangla area shows a gradual regressive trend, testified by the presence of early diagenetic dolomitic limestones possibly related to lateral migration of brines from more restricted inner environments with high Mg/Ca ratio. In the central part of this lithozone, at the top of sublithozone (a1), a sequence made of ferruginous oolites, thin rudites and calcarenites with vertical borings at the top suggests low sedimentation rates and possibly a disconformity. In the Zumlung-Khurna units (Tsarap valley close to the Zara Chu confluence, the lower Kioto (Para Fm.) in the same stratigraphic position displays a plurimetric conglomerate horizon (clasts with megalodontids), attesting to a regional regression with emersion within lithozone (a). Baud et al. (1982) in the Nari Narsang section (Khurna Unit) describe a possibly coeval event at the top of the Para Fm. (level 3, fig. 8D). Paleocurrents measured on cross-laminated calcarenites show prevalent northeastward transport direction.

Lithozone (b) mostly represents a high-energy storm-dominated shallow-water shelf with ooidal sand bars and still fine siliciclastic influx at the base. Paleocurrent indicators show bipolar northward to southwestward directions.

The Tagling Fm. (lithozones c, d, e, f, g) is characterized by less differentiated shelf environments, with a deepening trend in the Zangla area and lower-energy lithofacies associations with respect to lithozones (a) and (b). Open subtidal and storm-controlled shelf conditions are suggested for all of these lithozones. Comparison between lithofacies associations of the Zangla-Zozar and Ringdom-Spanboth sections suggests shallower shelf conditions to the west, where oolitic lithofacies, coral patch reefs and other shallow-water features are present up to the topmost Kioto layers. In the Zangla area higher-energy episodes (storm layers, bipolar cross-lamination, sand waves, bioclastic or crinoidal calcarenites) are more frequent and may indicate more external shelf environments. Paleocurrent directions are mainly towards the northeast, but bipolar cross-laminations point to east-west transport directions.

The occurrence of the high energy, marginal outer shelf upper Kioto lithozone (h) only in the Zangla Gompa area confirms the persistence of upper Triassic paleogeographic trends up to the Liassic (Fig. 4, 11). The intermittent terrigenous supply and the occurrence of marly horizons may be related to transgressive events and consequent deposition on the shelf of soil material formed on previously emerged areas. The frequent intercalation of ferruginous quartzose calcarenites and hybrid quartzarenites (A6) may also indicate transgressive pulses associated with low sedimentation rates. The thin rusty quartzarenite intercalations of lithozone (h) were possibly formed by similar processes.

Paleocurrent directions in lithozone (h) are mostly toward the N-NE. The uppermost portion of the Kioto regressive trend is truncated by the unconformable boundary with the overlying Ferruginous Oolite Fm. (Jadoul et al., 1985).

Sea-level changes and sequence stratigraphy.

The analysis has been carried out in particular on the Zangla-Namche La section, which was measured and studied in greater detail. Sublithozone (a1) of the Para Fm. may represent the Rhaetian supercycle UAB-1 (Haq et al., 1988). The thin calciruditic layers and ferruginous oolites comprised between sublithozones (a1) and (a2) could mark the sequence boundary at the Rhaetian-Hettangian boundary (Haq et al., 1987). The UAB-2 supercycle might include sublithozone (a2) ("Shelf Margin System Tract") and lithozone (b). The lower part of lithozone (b), with a renewal of fine siliciclastic yield, may represent the "Transgressive System Tract". The upper part of lithozone (b), with high-energy cross-laminated calcarenites could represent the "Highstand System Tract".

The ruditic layer between lithozones (b) and (c) marks the beginning of a new sequence, which might correspond to cycle UAB-3.1 (Early Sinemurian; Haq et al., 1988). At the base of this cycle the last shallow-water oolitic bars are observed. They are followed by a monotonous sequence of calcarenites and fossiliferous bioturbated micrites which indicate a relative deepening in the shelf facies.

The lack of biostratigraphic data on lithozones (b, c, d, e, f, g) prevents sequence stratigraphy considerations in the upper Kioto Group (Tagling Fm.) even if the occurrence of dark marly intervals within lithozone (f) may be ascribed to the effect of the Toarcian anoxic event (Jadoul et al., in prep.). We hypothesize that sequences formed by lithozones (d+e) and (f+g) represent upper Liassic cycles, in which the transgressive tract is characterized by lithozones (d) and (f) with abundant fine terrigenous supply. We suppose that these sequences may be correlated with large scale cycles (2.3, 4.5-5.7 m.y.) of Bayer & McGhee (1986).

Low rate sedimentation in the Tagling Formation (b, c, d, e, f, g lithozones), with average values from 11 to about 7 m/m.y. (depending if the topmost Kioto layers are considered still Liassic or lower Dogger) may be explained with periodic episodes of non-deposition (hardgrounds) or erosion.

The high-frequency cyclicity, locally observed in many lithozones, may be the response of sediments to sea-level changes in differing subsiding storm-dominated shelf conditions (Einsele, 1982). In the shallow-water lower Kioto Group of Rhaetian age, sedimentation rates were about 20 m/m.y. Lithozone (h), dated as uppermost Liassic or lower Dogger, could represent a transgressive sequence, possibly corresponding to the Aalenian LZA-1 supercycle (Haq et al., 1988). The unconformable fossiliferous ironstone sequence (Ferruginous Oolite Formation; Jadoul et al., 1985) onlapped the top of the Kioto Group in the upper Bathonian (Cycle 3.1) to middle Callovian (Cycle 3.2) (supercycle LZA-3 of Haq et al., 1988).

	SPITI (Hayden, 1904)	ZANSKAR (this work)	KHURNAK (Stutz, 1988)	MARKHA (Stutz, 1988)
DOGGER		FeOOLITE FM.	gap	LALUNG LA FM.
LIAS		TAGLING FM. g-h c-f	TAGLING FM. 10 9	
RHAETIAN	Megalodon Lst.	PARA FM. b a2 a1	PARA FM. 8 7 6	
NORIAN	Quartzite Series Monotis Shale Coral Limestone Juvavites Beds	"QUARTZITE SERIES" c b b a	KHAR SERIES 5 4-5 3 2	DOLTO FORMATION
Late CARNIAN	Tropites Lst.	ZOZAR FM.	SAMLUNG SERIES 1	
Early	Grey Beds Halobia Beds	upper HANSE		
LADINIAN	Daonella Lst. Daonella Sh.	FORMATION lower	Hangkhar Member	Hangkhar Member

Tab. 6 - Mid-Triassic to mid-Jurassic stratigraphic framework for the Tethys Himalaya sequence.

Triassic-Jurassic evolution of the Zanskar Tethys Himalaya.

Stratigraphy and facies analysis carried out on the sedimentary succession of the Zangla Unit, along with field observations made during the 1987 expedition in the Zumlung and Khurna Units, allow us to tentatively reconstruct the sedimentary evolution of the Zanskar passive margin during Late Triassic to mid-Jurassic times. Comparisons are also made with the more distal sedimentary successions cropping out in the eastern Spiti region and in the northern Khurnak-Markha area (Tab. 6; Baud et al., 1982; Fuchs, 1982b; 1984; 1986; Stutz & Steck, 1986; Bhargava, 1987; Stutz, 1988, pp. 46-73).

The Zangla Unit represents the most shoreward part of the southern Neotethyan margin preserved in the Zanskar mountains. In late Carnian times, a regional shallowing-upward trend is testified by the northeastward progradation of the Zozar carbonate platform on top of early Carnian basinal muds (upper Hanse Fm., corresponding to the "Grey Beds" of Spiti; Bhargava, 1987; G. Fuchs, pers. comm. 1989).

The first shallow-water carbonate sediments are found in the western area (west of Tongde La), where growth of the carbonate platform probably took place since the early Carnian. The occurrence of Early?/Middle Triassic calciturbidites in the northern paleogeographic domains (Hangkhar Member; Stutz, 1988) may indicate an even earlier initial growth of carbonate ramps on the Indian margin.

During the Carnian, low-relief carbonate masses (sensu Wilson, 1975), passing laterally to distal ramps, prograded in large areas of the Zangla Unit. These platforms were generally formed by crinoid and bryozoan colonies and generally were not characterized by a rigid framework. They extended towards the Spiti region in the east (shallow-water facies in the "Tropites Limestone"; Hayden, 1904; Fuchs, 1982b) and to the Zumlung Unit in the north, and reached their maximum extension during the late Carnian regression. The Khurna Unit may already represent the transition to the more distal part of the Tethyan margin represented in the Nyimaling region by the upper Samlung Series (Stutz, 1988).

In the Norian, sudden increase of quartzo-feldspathic detritus derived from erosion of the Indian continent points to rejuvenation and possibly to thermal uplift due to active extensional tectonics affecting the northern Gondwanaland margin from western India (Biswas, 1987) up to northwestern Australia (Von Rad & Exon, 1983; Baumgartner et al., 1989).

The sandstones of the Quartzite Series were deposited on the proximal Zanskar shelf, while toward the north-east more distal and deeper offshore environments are testified by the Khar Series (Stutz, 1988). This shaly unit, the upper part of which ranges from the late early Norian to the late middle Norian, is directly comparable with the succession of Spiti ("Juvavites Beds" to "Quartzite Series"; Hayden, 1904).

Further to the north-east, in the Markha valley, the terrigenous units are replaced by the basinal slates of the Dolto Formation (Stutz, 1988), which continues up in the Liassic and is therefore lateral equivalent of both the Quartzite Series and the Kioto Group. Similar distal pelites of Norian age, as testified by the occurrence of *Monotis sali-*

naria, crop out in the Lamayuru Unit, just south of the Indus suture (Fuchs, 1979). These deep water muds represent the continental rise sediments of the Indian margin, extending as far as central Himalaya (Heim & Gansser, 1939) and southern Tibet (Burg & Chen, 1984).

In Rhaetian times, widespread carbonate platform sedimentation resumed on the Zanskar margin, as testified by the occurrence of the Para Formation both in the Zangla and Northern Zanskar tectonic units. The base of the Kioto Group is probably slightly heterochronous. Limestone facies are developed in the north since the late Norian (Baud et el., 1982), while the inner Zanskar margin was characterized by mixed carbonate-siliciclastic sedimentation up to the earliest Rhaetian. The much greater thickness of the Para Formation in the north with respect to the Zangla Unit suggests either lateral relationships between the upper Quartzite Series and the lower Kioto Group or disconformable relationships between the two units in the more proximal Zangla Unit.

The Para Formation of the Zangla Unit mostly represents back-reef environments, while influence of reefal sedimentation is documented in the Zumlung Unit. In the Khurna Unit, reef deposits 120-150 m thick are testified by the occurrence of bryozoan and sponge patch-reefs or coral colonies interbedded with biocalcarenites and typical dark megalodontid limestones.

In Liassic times, muddy calcarenitic sequences of carbonate shelf sedimentation characterized most of the Zanskar region. The Tagling Formation of the Zangla Unit testifies to storm-dominated inner to outer shelf environments, while in the Zumlung Unit shallow-water oolitic sediments are widely represented. These deposits extended in the north up to the Khurna and Langtang regions, where they interfinger with the deep-water pelites of the Dolto Formation.

In the early Dogger, the Zanskar region was characterized by different palaeogeography: reduced sedimentation in the Zangla Unit and shallow-water oo-bioclastic facies with high sedimentation rates in the Zumlung Unit (Jadoul et al., in prep.). The upper Dogger was characterized by outer shelf belemnite-bearing carbonate-quartzarenite sequences with frequent gaps, as testified by the occurrence of ferruginous calcarenites and phosphatic nodules (Zumlung and Khurna Units). These sediments may testify to tilting and fragmentation of the Liassic shelf, causing uplift and renewed erosion of the Indian craton to the south and increasing terrigenous supply to the northern Tethyan shores. The proximal areas preserved in the Zangla Unit were at times characterized by non-deposition and by-passing of siliciclastic detritus, while the Laptal Beds were being deposited in deepening environments in the northern Zumlung and Khurna Units. During major eustatic lowstands, active tectonics may have caused prolonged emersions and formation of disconformities in large parts of the Zanskar region. This stage was characterized by local extensional volcanism reported in the distal Zanskar margin (Honegger, 1983; Bassoullet & Colchen, 1987) and probably by crustal uplift linked with the initiation of rifting of Asian fragments from Gondwanaland (Audley-Charles et al., 1988; Gaetani & Garzanti, 1989).

Marine sedimentation resumed in the Zangla, Zumlung and Khurna tectonic units during the late Bathonian to the middle Callovian, with deposition of outer shelf ironstone-bearing arenitic sequences (Ferruginous Oolite Fm.; Jadoul et al., 1985; Garzanti et al., 1989). This formation correlates distally with the Lalung La calciturbidites of the Markha Unit, characterized by the occurrence of reworked phosphates and representing the continental rise succession. A major sedimentary gap ascribed to non-deposition and erosion due to action of geostrophic currents along the continental slope is testified in the distal Indian margin (Shillakong to Khurnak regions) by the lack of Middle Jurassic to Early Cretaceous sediments (Bassoullet et al., 1983; Fuchs, 1986; Stutz, 1988).

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REFERENCES

Aigner T. (1985) - Storm depositional systems. Dynamic stratigraphy in modern and ancient shallow marine sequences. *Lecture Notes in Earth Science 3*, 174 pp., 83 fig., Springer- Verlag, Berlin.

Allasinaz A. & Zardini R. (1978) - *Megalodontidae* e *Dicerocardiidae* del Triassico superiore di Cortina d'Ampezzo. *Mem. Riv. It. Paleont. Strat.*, n. 15, v. 1 (testo), 144 pp., 28 fig.; v. 2, 35 pl., Milano.

Audley-Charles M.G., Ballantyne P.D. & Hall R. (1988) - Mesozoic-Cenozoic rift-drift sequence of Asian fragments from Gondwanaland. *Tectonophysics*, v. 155, pp. 317-330, Amsterdam.

Awasthi N. (1961) - Authigenic tourmaline and zircon in the Vindhyan formations of Sone Valley, Mirzapur district, Uttar Pradesh, India. *Journ. Sedim. Petrol.*, v. 31, pp. 482-484, Tulsa.

Bassoullet J.P. & Colchen M. (1987) - Découverte d'*Archaeosepta platierensis* Wernli, 1970, foraminifère du Dogger alpin, Himalaya du Ladakh (Indie). *Géobios*, v. 20, pp. 549-555, Lyon.

Bassoullet J.P., Colchen M., Juteau Th., Marcoux J., Mascle G. & Reibel G. (1983) - Geological studies in the Indus suture zone of Ladakh (Himalayas). In Gupta V.J. (Ed.) - Stratigraphy and structure of Kashmir and Ladakh Himalaya. *Contributions to Himalayan Geology 2*, pp. 96-124, Hindustani, Delhi.

Baud A. et al. (11 co-authors) (1982) - Le contact Gondwana-péri-Gondwana dans le Zanskar oriental (Ladakh, Himalaya). *Bull. Soc. Géol. France*, v. 24, n. 2, pp. 241-361, Paris.

Baud A., Gaetani M., Garzanti E., Fois E., Nicora A. & Tintori A. (1984) - Geological observations in southeastern Zanskar and adjacent Lahul area (northwestern Himalaya). *Ecl. Geol.*

Helv., v. 77, n. 1, pp. 171-197, Basel.

Baumgartner P.O., Marcoux J. & Scientific parties of ODP Legs 122-123 (1989) - Mesozoic facies evolution of the NW Australian margin (Legs 122-123): Does it document Australian breakup or Neotethys history? *AAPG Ann. Meeting*, San Antonio (Abstract).

Bayer U. & McGhee G. (1986) - Cyclic pattern in the Paleozoic and Mesozoic: implications for time scale calibrations. *Paleoceanography*, v. 1, n. 4, pp. 383-402, Washington.

Bhargava O.N. (1987) - Stratigraphy, microfacies and palaeoenvironment of the Lilang Group (Scythian - Dogger), Spiti Valley, Himachal Himalaya, India. *Journ. Palaeont. Soc. India*, v. 32, pp. 92-107, Lucknow.

Bhargava O.N. & Bassi U.K. (1985) - Upper Triassic Coral knoll reefs: Middle Norian, Spiti-Kinnaur, Himachal Himalaya, India. *Facies*, v. 12, pp. 219-242, 5 pl., 4 fig., Erlangen.

Biswas S.K. (1987) - Regional tectonic framework, structure and evolution of the western marginal basins of India. *Tectonophysics*, v. 135, pp. 307-327, Amsterdam.

Blatt H. (1967) - Provenance determinations and recycling of sediments. *Journ. Sedim. Petrol.*, v. 37, pp. 1031-1044, Tulsa.

Blatt H. (1979) - Diagenetic processes in sandstones. *Soc. Econ. Paleont. Min.*, spec. publ. 26, pp. 141-157, Tulsa.

Brookfield M.E. & Andrews-Speed C.P. (1984) - Sedimentology, petrography and tectonic significance of the shelf, flysch and molasse clastic deposits across the Indus suture zone. *Sedim. Geol.*, v. 40, pp. 287-291, Amsterdam.

Burg J.P. & Chen G.M. (1984) - Tectonics and structural zonation of southern Tibet, China. *Nature*, v. 311, pp. 219-223, London.

Cameron K.L. & Blatt H. (1971) - Durabilities of sand size schist and "volcanic" rock fragments during fluvial transport, Elk Creek, Black Hills, South Dakota. *Journ. Sedim. Petrol.*, v. 41, pp. 565-576, Tulsa.

Colchen M., Mascle G. & Van Haver Th. (1986) - Some aspects of collision tectonics in the Indus suture zone, Ladakh. In Coward M.P. & Ries A.C. (Eds.) - Collision tectonics. *Geol. Soc.*, spec. publ. 19, pp. 173-184, London.

Dickinson W.R. (1970) - Interpreting detrital modes of greywacke and arkose. *Journ. Sedim. Petrol.*, v. 40, pp. 695-707, Tulsa.

Dickinson W.R. & Suczek C.A. (1979) - Plate tectonics and sandstone composition. *Bull. Am. Ass. Petrol. Geol.*, v. 63, pp. 2164-2172, Tulsa.

Dutta P.K. & Suttner L.J. (1986) - Alluvial sandstone composition and paleoclimate. II. Authigenic mineralogy. *Journ. Sedim. Petrol.*, v. 56, pp. 346-358, Tulsa.

Einsele G. (1982) - Response of sediments to sea-level changes in differing subsiding storm dominated marginal and epeiric basins. In Einsele G. & Seilacher A. (Eds.) - Sedimentary and evolutionary cycles. *Lecture Notes in Earth Science 1*, pp. 68-97, Springer Verlag, Berlin.

Flügel E. (1981) - Paleoecology and facies of Upper Triassic reefs in the Northern Calcareous Alps. *Soc. Econ. Paleont. Min.*, spec. publ. 30, pp. 291-359, 26 fig., 15 tab., Tulsa.

Folk R.L. (1980) - Petrology of sedimentary rocks. V. of 182 pp., Austin.

Franzinelli E. & Potter P.E. (1983) - Petrology, chemistry and texture of modern river sands, Amazon river system. *Journ. Geol.*, v. 91, pp. 23-39, Chicago.

Fuchs G. (1979) - On the geology of western Ladakh. *Jahrb. Geol. Bundesanst.*, v. 122, n. 2, pp. 513-540, Wien.

Fuchs G. (1982a) - The geology of western Zanskar. *Jahrb. Geol. Bundesanst.*, v. 124, n. 1, pp. 1-50, Wien.

Fuchs G. (1982b) - The geology of the Pin valley in Spiti, H.P., India. *Jahrb. Geol. Bundesanst.*, v. 124, n. 2, pp. 325-359, 3 pl., 21 fig., Wien.

Fuchs G. (1984) - Note on the geology of the Markha-Nimaling area in Ladakh (India). *Jahrb. Geol. Bundesanst.*, v. 127, n. 1, pp. 5-12, Wien.

Fuchs G. (1986) - The geology of the Markha-Khurnak region in Ladakh (India). *Jahrb. Geol. Bundesanst.*, v. 128, n. 3, pp. 403-437, Wien.

Fuchs G. (1987) - The geology of southern Zanskar (Ladakh) - Evidence for the autochthony of the Tethys Zone of the Himalaya. *Jahrb. Geol. Bundesanst.*, v. 130, n. 4, pp. 465-491, Wien.

Gaetani M., Casnedi R., Fois E., Garzanti E., Jadoul F., Nicora A. & Tintori A. (1986) - Stratigraphy of the Tethys Himalaya in Zanskar, Ladakh. Initial report. *Riv. It. Paleont. Strat.*, v. 91 (1985), n. 4, pp. 443-478, 16 fig., Milano.

Gaetani M. & Garzanti E. (1989) - Multicyclic evolution of the northwestern margin of the Indian plate. *Int. Geol. Congr.*, Washington (Abstract).

Gaetani M., Garzanti E. & Jadoul F. (1985) - Main structural elements of Zanskar, NW Himalaya (India). *Rend Soc. Geol. It.*, v. 8, pp. 3-8, Roma.

Gansser A. (1964) - Geology of the Himalayas. V. of 289 pp., Wiley, New York.

Garzanti E. (1986) - Storia sedimentaria del margine continentale settentrionale della placca indiana (Tethys Himalaya, Ladakh, India). V. of 250 pp., *Tesi di Dottorato*, Univ. Milano.

Garzanti E. & Brignoli G. (1989) - Low temperature metamorphism in the Zanskar sedimentary nappes (NW Himalaya, India). *Ecl. Geol. Helv.*, v. 82, n. 2, pp. 669-684, Basel.

Garzanti E., Casnedi R. & Jadoul F. (1986) - Sedimentary evidence of a Cambro-Ordovician orogenic event in the Northwestern Himalaya. *Sedim. Geol.*, v. 48, pp. 237-265, Amsterdam.

Garzanti E., Haas R. & Jadoul F. (1989) - Ironstones in the Mesozoic passive margin sequence of the Tethys Himalaya (Northern India): sedimentology and metamorphism. In Young T.P. & Taylor W.E.G. (Eds.) - Phanerozoic ironstones. *Geol. Soc.*, spec. publ. 46, pp. 229-244, London.

Gazdzicki A. (1974) - Rhaetian microfacies, stratigraphy and facial development in the Tatra Mts. *Acta Geol. Pol.*, v. 24, n. 1, pp. 2-96, Warszawa.

Gazdzicki A. (1983) - Foraminifers and biostratigraphy of Upper Triassic and Lower Jurassic of the Slovakian and Polish Carpathian. *Palaeont. Pol.*, v. 44, pp. 110-169, Warszawa.

Gazdzicki A., Kozur H., Mock R. & Trammer J. (1979) - The Norian- Rhaetian boundary in the light of micropaleontological data. *Geol. Rozpr. Porocila*, v. 22, n. 1, pp. 61-76, Ljubljana.

Gokhale K.V.G.K. & Bagchi T.C. (1959) - Authigenic tourmaline in the Banganapally Stage (Kurnool System), India. *Jour. Sedim. Petrol.*, v. 29, pp. 468-469, Tulsa.

Gupta V.J. (1976) - The stratigraphic position of the Kioto Limestone of Himalaya. *Journ. Geol. Soc. India*, v. 17, n. 3, pp. 346-352, Calcutta.

Haq B.U., Hardenbol J. & Vail P.R. (1987) - Chronology of fluctuating sea levels since the Triassic (250 My ago to the present). *Science*, v. 235, pp. 1156-1167, Washington.

Haq B.U., Hardenbol J. & Vail P.R. (1988) - Mesozoic and Cenozoic chronostratigraphy and eustatic cycles. In Wilgus C.K. (Ed.) - Sea-level changes: an integrated approach. *Soc. Econ. Paleont. Min.*, spec. publ. 42, pp. 71-108, Tulsa.

Harris W.B., Zullo V.A. & Otte L.J. (1986) - Eocene carbonate facies of the North Carolina coastal plain. In Textoris D. (Ed.) - Soc. Econ. Paleont. Miner. Midyear Meeting, Field guidebooks, pp. 253-332, Raleigh.

Hayden H.H. (1904) - The geology of Spiti, with part of Bashahr and Rupshu. *Mem. Geol. Surv. India*, v. 36, pp. 1-129, Calcutta.

Hayden H.H. (1908) - Geography and geology of the Himalaya. *Geol. Surv. India*, pt. 4, pp. 233-236, Calcutta.

Heim A. & Gansser A. (1939) - Central Himalaya, geological observations of the Swiss expedition, 1936. *Mem. Soc. Helv. Sci. Nat.*, v. 73, n. 1, pp. 1-245, Basel.

Honegger K.H. (1983) - Strukturen und Metamorphose im Zanskar Kristallin (Ladakh-Kashmir, Indien). *PhD Thesis, Univ. Zürich*, 177 pp., Zürich.

Jadoul F., Fois E., Tintori A. & Garzanti E. (1985) - Preliminary results on Jurassic stratigraphy in Zanskar (NW Himalaya). *Rend. Soc. Geol. It.*, v. 8, pp. 9-13, 2 fig., Roma.

Jain A.K., Goel R.K. & Nair N.G.K. (1980) - Implications of pre-Mesozoic orogeny in the geological evolution of the Himalaya and Indo-Gangetic plains. *Tectonophysics*, v. 62, pp. 67-86, Amsterdam.

Johnsson M.J., Stallard R.F. & Meade R.H. (1988) - First cycle quartz arenites in the Orinoco River basin, Venezuela and Columbia. *Journ. Geol.*, v. 96, pp. 263-277, Chicago.

Kanwar S.S. & Bhandari A.K. (1979) - Stratigraphy, structure and sedimentation of part of Lahaul and Spiti District, Himachal Pradesh. *Miscellaneous Publ. Geol. Surv. India*, v. 41 (1976), n. 1, pp. 169-178, Calcutta.

Kelemen P.B. & Sonnenfeld M.D. (1983) - Stratigraphy, structure, petrology and local tectonics, Central Ladakh, NW Himalaya. *Schw. Miner. Petrogr. Mitt.*, v.63, pp. 267-287, Zürich.

Lahiri D. (1964) - Petrology of the Vindhyan rocks around Rohtasgarh, India. *Journ. Sedim. Petrol.*, v. 34, pp. 270-280, Tulsa.

Mack G.H. (1978) - The survivability of labile light-mineral grains in fluvial, aeolian and littoral marine environments: the Permian Cutler and Cedar Mesa Formations, Moab, Utah. *Sedimentology*, v. 25, pp. 587-604, Oxford.

Mack G.H. (1981) - Composition of modern stream sand in a humid climate derived from a low-grade metamorphic and sedimentary foreland fold-thrust belt of north Georgia. *Journ. Sedim. Petrol.*, v. 51, pp. 1247-1258, Tulsa.

McCubbin D.G. (1982) - Barrier-island and strandplain facies. In Scholle P.A. & Spearing D. (Eds.) - Sandstone depositional environments. *Am. Ass. Petr. Geol.*, Mem. 31, pp. 247-279, Tulsa.

Nanda M.M. & Singh M.P. (1977) - Stratigraphy and sedimentation of the Zanskar area, Ladakh and adjoining parts of the Lahaul region of Himachal Pradesh. *Himalayan Geol.*, v. 6, pp. 367- 388, Dehra Dun.

Odom I.E., Doe T.W. & Dott R.H. (1976) - Nature of feldspar-grain size relations in some quartz-rich sandstones. *Journ. Sedim. Petrol.*, v. 46, pp. 862-870, Tulsa.

Potter P.E. (1978) - Petrology and chemistry of modern big river sands. *Journ. Geol.*, v. 86, pp. 423-449, Chicago.

Raina V.K. & Bhattacharyya D.P. (1977) - The geology of a part of the Chharap and Sarchu valleys, Lahaul and Spiti District, Himachal Pradesh. Golden Jubilee Vol. *Geol. Min. Met. Soc. India*, v. 11 (1974), pp. 129-142, Delhi.

Rajulu G.B.V. & Nagaraja H.R. (1969) - Authigenic tourmalines from the lower Kaladgi sandstones, Jamkhandi, Mysore State. *Journ. Sedim. Petrol.*, v. 39, pp. 391-393, Tulsa.

Reuber I., Colchen M. & Mevel C. (1987) - The geodynamic evolution of the South-Tethyan margin in Zanskar, NW-Himalaya, as revealed by the Spongtang ophiolitic melanges. *Geodinamica Acta*, v. 1, pp. 283-296, Paris.

Schäfer P. & Fois E. (1987) - Systematic and evolution of Triassic Bryozoa. *Geol. Paleont.*, v. 21, pp. 173-225, 15 pl., 3 fig., 15 tab., Marburg.

Searle M.P. (1986) - Structural evolution and sequence of thrusting in the High Himalayan, Tibetan-Tethys and Indus suture zones of Zanskar and Ladakh, western Himalaya. *Journ. Struct. Geol.*, v. 8, pp. 923-936, Oxford.

Searle M.P., Cooper D.J.W. & Rex A.J. (1988) - Collision tectonics of the Ladakh-Zanskar Himalaya. *Phil. Trans. R. Soc.*, A 326, pp. 117-150, London.

Srikantia S.V. (1981) - The lithostratigraphy, sedimentation and structure of Proterozoic-Phanerozoic formations of Spiti basin in the higher Himalaya of Himachal Pradesh, India. In Sinha A. (Ed.) - Contemporary Geoscientific Res. Himalaya, v. 1, pp. 41-48, Singh, Dehra Dun.

Srikantia S.V., Ganesan T.M., Rao P.N., Sinha P.K. & Tirkey B. (1980) - Geology of Zanskar area, Ladakh Himalaya. *Himalayan Geol.*, v. 8, pp. 1009-1033, Dehra Dun.

Stoliczka A. (1866) - Summary of the geological observations during a visit to the provinces Rupshu Karnag, South Ladakh, Zanskar, Sumdo and Dras of western Tibet. *Mem. Geol. Surv. India*, v. 5, pp. 337-354, Calcutta.

Stutz E. (1988) - Géologie de la chaîne de Nyimaling aux confins du Ladakh et du Rupshu (NW-Himalaya, Inde). Evolution paléogéographique et tectonique d'un segment de la marge nord-indienne. *Mém. Géol. Lausanne*, n. 3, v. of 149 pp., Imprivite S.A., Lausanne.

Stutz E. & Steck A. (1986) - La terminaison occidentale du cristallin du Tso Morari (Haut Himalaya; Ladakh méridional, Inde): subdivision et tectonique de nappe. *Ecl. Geol. Helv.*, v. 79, n. 2, pp. 253-269, Basel.

Suttner L.J. & Dutta P.K. (1986) - Alluvial sandstone composition and paleoclimate. I. Framework mineralogy. *Journ. Sedim. Petrol.*, v. 56, pp. 329-345, Tulsa.

Von Rad U. & Exon N.F. (1983) - Mesozoic-Cenozoic sedimentary and volcanic evolution of the starved passive continental margin off Northwest Australia. *Am. Ass. Petr. Geol. Mem.*, n. 34, pp. 253-281, Tulsa.

Walker R.G. (1984) - Shelf and shallow marine sands. In Walker R.G. (Ed.) - Facies models. *Geosc. Canada Reprint Ser. 1*, pp. 141-170.

Wilson J.L. (1975) - Carbonate Facies in Geologic History. V. of 471 pp., 30 pl., 18 fig., Springer-Verlag, Berlin.

Zaninetti L. (1976) - Les Foraminifères du Trias. Essai de synthèse et corrélation entre les domaines mésogéens européen et asiatique. *Riv. It. Paleont. Strat.*, v. 82, n. 1, pp. 1-158, 24 pl., 12 fig., Milano.

Zuffa G.G. (1980) - Hybrid arenites: their composition and classification. *Journ. Sedim. Petrol.*, v. 50, pp. 21-29, 3 fig., Tulsa.

Zuffa G.G. (1987) - Unravelling hinterland and offshore palaeogeography from deep-water arenites. In Leggett J.K. & Zuffa G.G. (Eds.) - Marine clastic sedimentology, pp. 39-61, Graham & Trotman, London.

PLATE 38

Zozar and Quartzite Series microfacies.

Fig. 1 - a) *Aulotortus communis* (Kristan, 1957). b) *Aulotortus tenuis* (Kristan, 1957). Zozar Fm., member b; Zangla-Namche La section. Sample J157; x 27.4.

Fig. 2 - *Aulotortus friedli* (Kristan-Tollmann, 1962). Zozar Fm., member b; Zangla-Namche La section. Sample J157; x 37.6.

Fig. 3 - *Aulotortus friedli* (Kristan-Tollmann, 1962). Zozar Fm.; Tanze Section. Sample HZ429; x 27.4.

Fig. 4 - *Aulotortus sinuosus* Weynschenk, 1956. Zozar Fm.; Zangla-Namche La section. Sample J157; x 24.

Fig. 5 - Bioclastic wackestone rich in bryozoans. a) *Zozariella stellata* Schäfer & Fois, 1987; b) *Tebitopora orientalis* Zhao-Xun, 1984; c) *Dyscritella rhomboporata* Schäfer & Fois, 1987. Zozar Fm., member a; Phirtse Chu section. Sample HP19A; x 2.1.

Fig. 6 - Oncoid-bioclastic rudstone. a) *Solenopora* sp. Zozar Fm.; Jinshen section. Sample HP17; x 3.3.
Fig. 7 - *Aulotortus tenuis* (Kristan, 1957). Zozar Fm.; Tanze section. Sample HZ431; x 27.4.
Fig. 8 - *Aulotortus communis* (Kristan, 1957). Quartzite Series, upper member c; Zangla-Namche La section. Sample J205; x 27.4.
Fig. 9 - *Aulotortus communis* (Kristan, 1957). Quartzite Series; Zozar 1 section. Sample HS22; x 27.4.
Fig. 10,11 - *Aulotortus friedli* (Kristan-Tollmann, 1962). Quartzite Series, upper member c; Zangla-Namche La section. Sample J205; x 27.4.
Fig. 12 - *Aulotortus friedli* (Kristan-Tollmann, 1962). Quartzite Series; Zozar 1 section. Sample HS22; x 27.4.
Fig. 13 - *Aulotortus sinuosus* (Weynschenk, 1956). Quartzite Series, member a; Tanze section. Sample HZ444; x 27.4.
Fig. 14 - *Aulotortus friedli* (Kristan-Tollmann, 1962). Quartzite Series, member a; Tanze section. Sample HZ443; x 27.4.
Fig. 15 - *Auloconus permodiscoides* (Oberhauser, 1964). Quartzite Series, member a; Tanze section. Sample HZ444; x 27.4.
Fig. 16 - *Aulotortus sinuosus* (Weynschenk, 1956). Quartzite Series; Zozar 1 section. Sample HS22; x 27.4.
Fig. 17 - *Agathammina* cf. *passerii* Ciarapica & Zaninetti, 1984. Quartzite Series, member b; Zangla-Namche La section. Sample J192; x 54.2.
Fig. 18 - *Agathammina* sp. Quartzite Series, member a; Zozar 1 section. Sample HS17; x 27.4.
Fig. 19 - *Halymeda*-like udoteaceans. Quartzite Series, upper member c; Zangla-Namche La section. Sample J205; x 30.5.

PLATE 39

Quartzite Series and Kioto Group (Para Formation) microfacies.

Fig. 1 - *Stylophyllum*. Quartzite Series; Zangla-Namche La section. Sample J200; x 6.7.
Fig. 2 - *Astraeomorpha crassisepta* Reuss, 1854. Quartzite Series, member a; Zangla-Namche La section. Sample J170; x 4.7.
Fig. 3 - *Solenopora* sp. Quartzite Series, member a; Tanze section. Sample HZ443; x 15.2.
Fig. 4 - a) *Aulotortus sinuosus* Weynschenk, 1956. b) *Triasina* sp. Quartzite Series, member c; Zangla-Namche La section. Sample J205; x 27.4.
Fig. 5 - *Triasina* cf. *hantkeni* Majzon, 1954. Quartzite Series, member c; Zangla-Namche La section. Sample J203; x 27.4.
Fig. 6 - *Aulotortus tumidus* (Kristan-Tollmann, 1964). Kioto Group, Para Fm.; Zozar 1 section. Sample HS10; x 27.4.
Fig. 7 - a) *Aulotortus* aff. *sinuosus* Weynschenk, 1956. b) *Aulotortus communis* (Kristan, 1957). Kioto Group, Para Fm.; Zozar 1 section. Sample HA43; x 13.5.
Fig. 8 - *Aulotortus communis* (Kristan, 1957). Kioto Group, Para Fm.; Zangla-Namche La section. Sample J214; x 27.4.
Fig. 9 - *Aulotortus friedli* (Kristan-Tollmann, 1962). Kioto Group, Para Fm.; Zozar 1 section. Sample HA41; x 27.4.
Fig. 10 - *Aulotortus sinuosus* Weynschenk, 1956. Kioto Group, Para Fm.; Zozar 1 section. Sample HS10; x 27.4.
Fig. 11 - *Aulotortus sinuosus* Weynschenk, 1956. Kioto Group, Para Fm.; Zozar 1 section. Sample HA43; x 27.4.
Fig. 12 - *Aulotortus tenuis* (Kristan, 1957). Kioto Group, Para Fm., sublithozone a1; Zozar 1 section. Sample HS10; x 27.4.
Fig. 13 - *Aulotortus* aff. *tumidus* (Kristan-Tollmann, 1964). Kioto Group, Para Fm., sublithozone a1; Zangla-Namche La section. Sample J214; x 27.4.
Fig. 14 - *Aulotortus sinuosus* Weynschenk, 1956. Kioto Group, Para Fm., sublithozone a1; Zangla-Namche La section. Sample J209; x 27.4.

PLATE 40

Kioto Group (Para and Tagling Formations).

Fig. 1 - *Triasina hantkeni* Majzon, 1954. Para Fm., sublithozone a1; Zangla-Namche La section. Sample J209; x 27.5.

Fig. 2 - *Lamellata* cf. *wahneri* Flügel & Sy, 1959. Tagling Fm., lithozone f; Zangla Gompa section. Sample J121; x 10.8.

Fig. 3 - *Triasina hantkeni* Majzon, 1954. Para Fm., sublithozone a1; Zangla-Namche La section. Sample J209; x 27.5.

Fig. 4 - Fragment of *Haurania* sp. Tagling Fm., lithozone h; Zangla Gompa section. Sample J130; x 27.5.

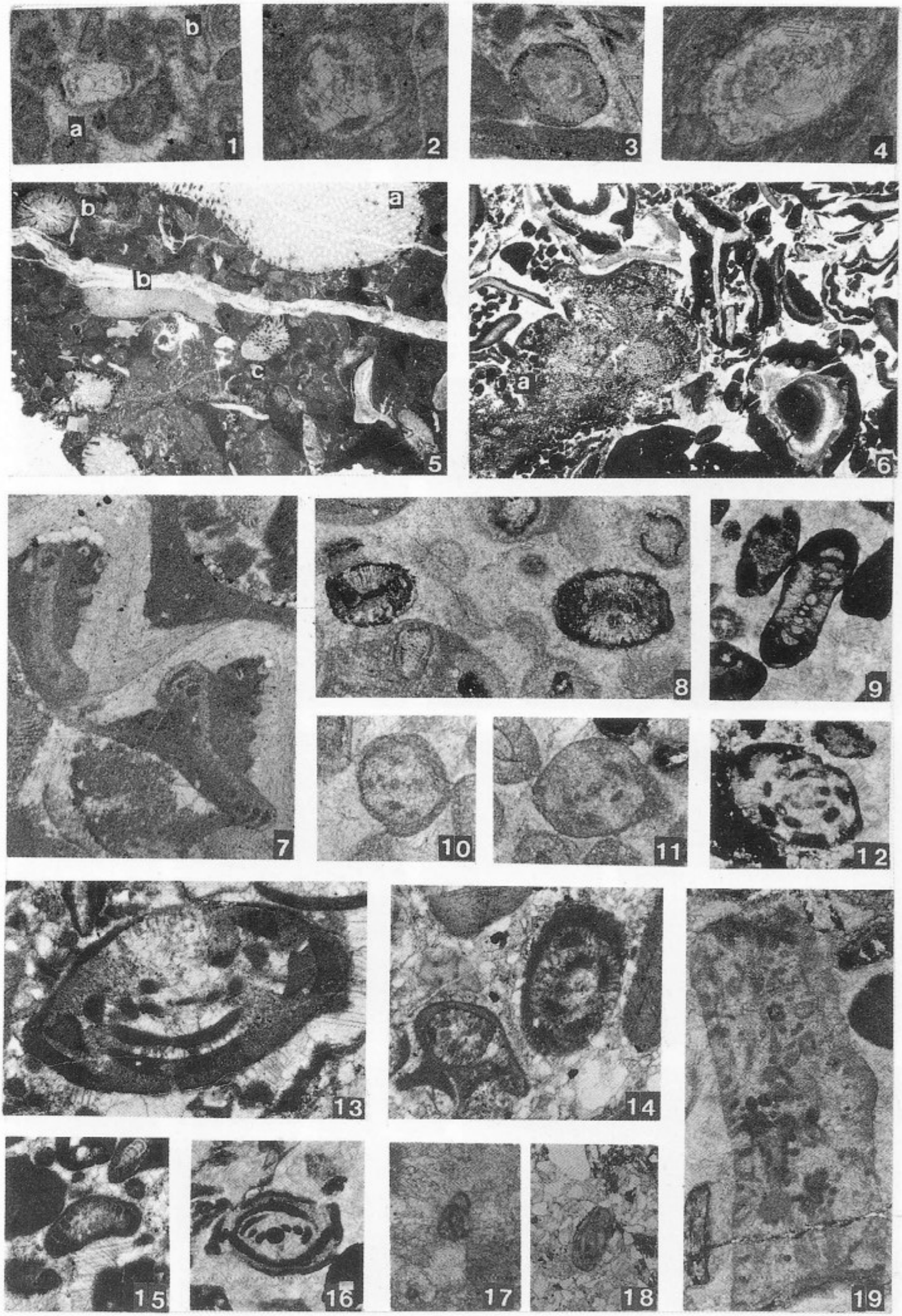
Fig. 5 - *Tetrataxis* sp., Tagling Fm., lithozone h; Zangla Gompa section. Sample J129; x 27.5.

Fig. 6 - a) *Halymeda*-like udoteaceans. b) *Aulotortus sinuosus* Weynschenk, 1956. Para Fm.; Zozar 1 section. Sample HA43; x 13.8.

Fig. 7 - Colonial scleractinians of "*Thecosmilia*". Para Fm., sublithozone a1; Zangla-Namche La section. Sample J213; x 8.6.

Fig. 8 - *Halymeda*-like udoteaceans. Para Fm., sublithozone a1; Zangla-Namche La section. Sample J211; x 18.9.

Fig. 9 - a) *Halymeda*-like udoteaceans. b) *Aulotortus sinuosus* Weynschenk, 1956. Para Fm., sublithozone a1; Zozar 1 section. Sample HA43; x 13.8.



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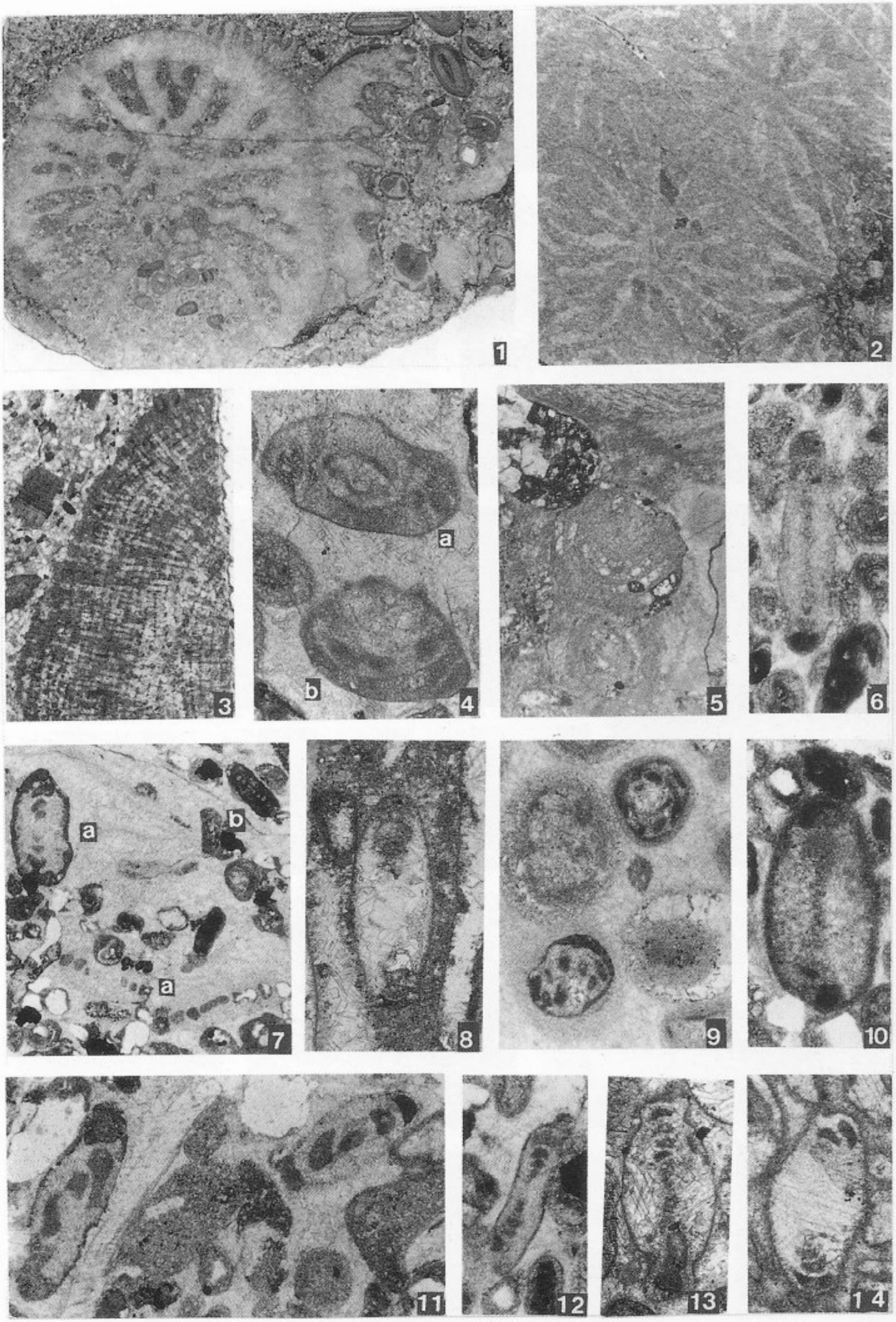
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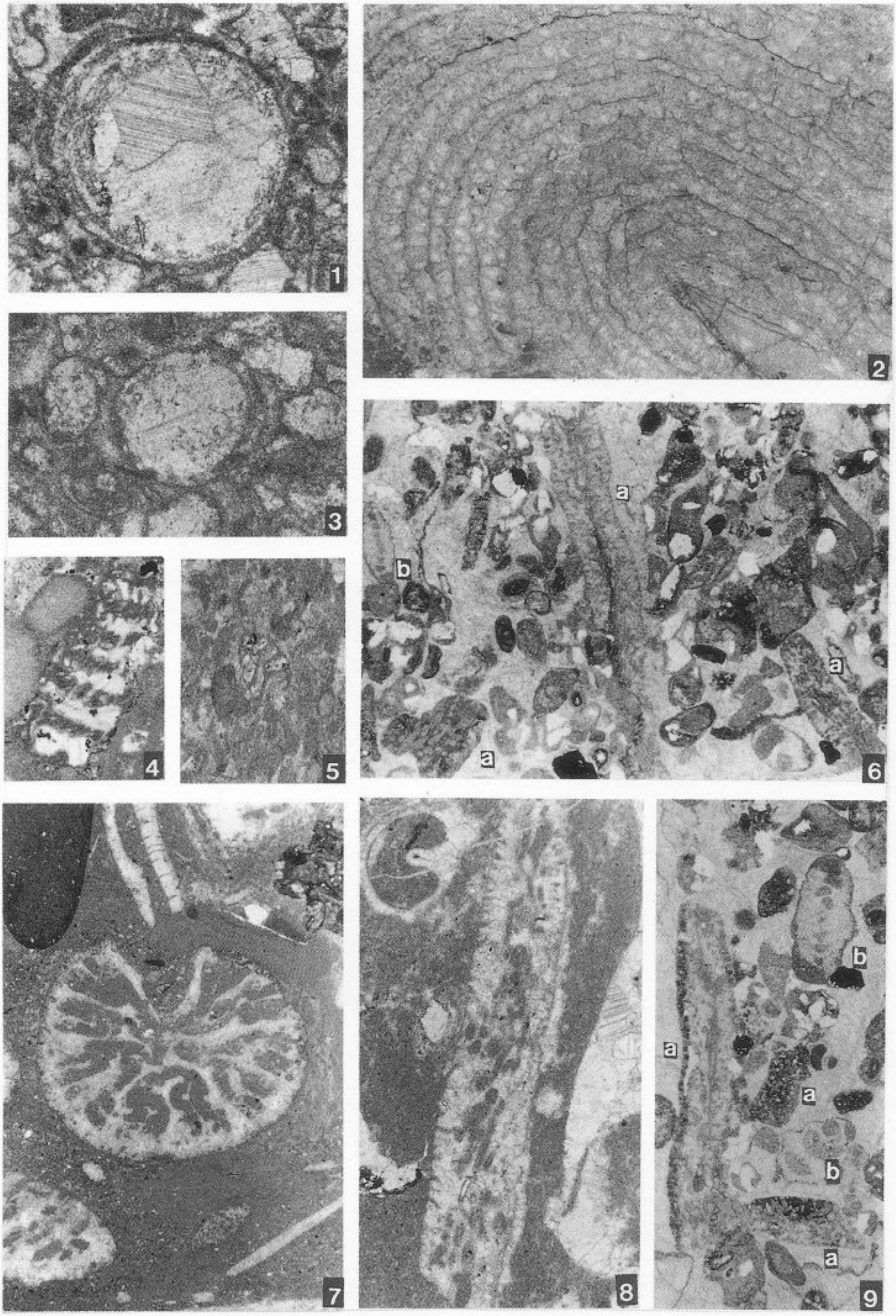
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