Riv. It. Paleont. Strat.	v. 89	n. 1	pp. 81–118	tav. 7–10	Ottobre 1983

UPPER CRETACEOUS AND PALEOCENE IN ZANSKAR RANGE (NW Himalaya)

MAURIZIO GAETANI**, ALDA NICORA*, ISABELLA PREMOLI SILVA*, ELISABETTA FOIS*, EDUARDO GARZANTI* & ANDREA TINTORI*

Key–words: Cretaceous, Paleocene, stratigraphy, Himalaya, India, Foraminifera, Algae, Crustacea.

Abstract. A detailed Upper Cretaceous/Paleocene stratigraphic section was measured from the Spanboth Chu Valley, High Himalaya Nappes. Placement of the Cretaceous–Tertiary boundary was refined, but some uncertitudes still remain because of poor exposure in this portion of the sequence. The Maastrichtian is characterized by floral and faunal assemblages consisting of *Cymopolia, Omphalocyclus, Siderolites* and *Odontogryphaea.* The Lower Paleocene seems to be missing, whilst the Middle to Upper Paleocene is characterized by *Rotalia, Daviesina, Lockhartia* and *Furcoporella* assemblages. Sandstone petrography and carbonate microfacies were analyzed for environmental interpretation. Moreover, a reconsideration of the recent published data on the Upper Cretaceous/Paleocene from the Zanskar mountains allows us to delineate a tentative depositional history of this part of the Indian continental margin during the considered time.

Introduction.

During the summer 1981 the valley of the Spanboth Chu was revisited. Due to shortage of time, only a new Cretaceous–Paleocene section was measured. The section is the closest to the Ringdom (Rangdum) Gompa (Gaetani et al., 1980). The present paper deals mainly with the description of this new section, which ranges from the Chikkim Limestone (Upper Cretaceous) up to the beds rich in *Daviesina* (Paleocene). It also reconsiders the Cretaceous–Paleocene sequence of the Spanboth Chu Valley in the regional context.

The Upper Cretaceous and the Paleocene of the Spanboth–Kangi La area

The Spanboth Chu Valley is one of the most accessible valley in the area and cuts a folded sequence from Permian up to Paleocene (Fig. 1,2). Unfortu-

* Dipartimento di Scienze della Terra dell'Università di Milano, via Mangiagalli 34, 20133 Milano.

** Istituto di Geologia, Via dei Verdi 75, 98100 Messina.

— A. Nicora and I. Premoli Silva studied the Foraminifera, E. Fois the Algae, A. Tintori the macrofossils, E. Garzanti the sandstone petrography, M. Gaetani the stratigraphy and correlations. All the authors, except IPS, made the survey on the field.

— Financial support from MPI 40%, Project Lithosphere.

nately, regional metamorphism affects the rocks in the middle of the valley, some 10 km from the Ringdom Gompa. It diminishes northward.

The base of the Cretaceous sequence is represented by the Giumal Sandstone (some 250–350 m thick) above the 20–30 m thick Spiti Shale (Late Jurassic–? Earliest Cretaceous). The Giumal Sandstone consists of a lower, thick bedded coarse sandstone unit, followed by dark grey, black silty shales intercalated with finer, grey to green sandstones. In the upper 15 m, 50–100 cm thick beds of coarse sublitharenite and thin conglomeratic beds also occur (own data; Fuchs, 1979, 1982 a; Bassoullet et al., 1982). The stratigraphic section studied in the Spanboth Valley is described below. Carbonate rocks classification according to Embry & Klovan (1971); sandstone petrography according to Folk (1980).

Chikkim Formation.

This unit was shortly described by Fuchs (1977, 1979, 1981, 1982 a) and by Bassoullet et al. (1982). We measured a section, with a total thickness of 89 m, starting along the narrow, deeply dissected creek, west of the Spanboth Chu, at 4400 m altitude (Fig. 2, 3).

The lower contact with the Giumal Sandstone is gradual over some 50 cm. It is characterized by grey calcarenites or strongly recrystallized immature sublitharenites, in 10–20 cm thick, poorly–defined beds. These are followed upwards by 65 m of dark limestones and marly limestones rich in Belemnites in the lower 7–8 m. Bedding is nodular, somewhat mottled at bottom, whereas upwards parallel thin laminae are recorded. Isolated small crystals and framboids of pyrite are widespread throughout. The clay content increases gradually upwards and becomes prominent in the upper 15 m, below the dark limestone layer, 10 m thick, at the top of the unit.

Unfortunately strong recrystallization and weak metamorphism affect all the sequence and the eleven samples collected contain only very poorly preserved Foraminifera. The Chikkim Fm. appears to be deposited under anoxic conditions, except for the basal ten meters, where nodular bedding and mottling suggest that some burrowing occurred at the time of deposition. According to Fuchs (1977, 1979) this formation has an early Late Cretaceous age.

Kangi La Formation.

Name. The name of Kangi La Flysch was introduced by Fuchs (1977) to designate the sandy and silty slates resting on the Chikkim Fm. Gaetani et al. (1980) followed this use. In the meantime, Srikantia and Razdan (1979) and Srikantia et al. (1980) referred the rock– units lying on the Giumal Sandstone in this area to a « Kanji Group» (1), but assigned a Paleocene–Eocene age to that Group.

(1) Kanji is only a different spelling of Kangi.

Since the name «Kangi La Flysch» has priority and the reference section is better defined (Fuchs, 1977), we continue to use the term Kangi La. Bassoullet et al. (1982) widened the definition of the Kangi La Flysch to include all the sedimentary sequence lying above the Chikkim Fm. up to the Eocene. We prefer to keep the original, more restricted definition of the unit.

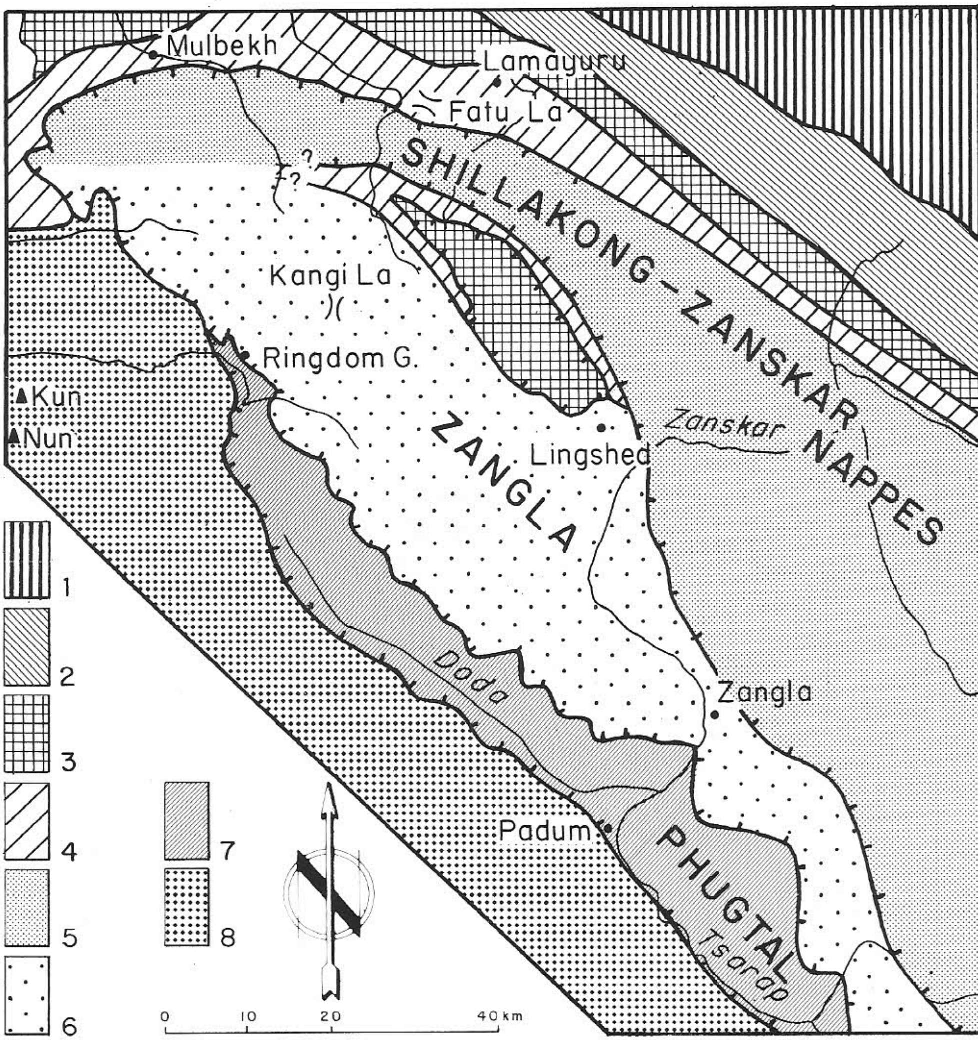


Fig. 1 – Sketch map of the main units of the High Himalaya. 1) Ladakh Batholith. 2) Indus Flysch and Molasse. 3) Dras and Nindam Flysch, Spongtang Klippe. 4) Lamayuru Zone. 5) Zanskar and Shillakong Units. 6) Zangla Unit. 7) Phugtal Unit. 8) High Himalayan Crystalline.

Lithology. The boundary with the Chikkim is fairly sharp and marked by a prominent increase of the silt and clay. This is reflected in a distinct morphological and erosional change in the present relief. The dominant lithotypes are grey to dark grey siltstones and silty marls. Slates and thin bedded sandstones are also present. Grey and green sandstones, rusty weathered, become common about two hundred metres above the base of the unit. Very thin bedded calcarenites with fragments of Bivalves, Crinoids and Belemnites may also occur. The topmost tens of metres of the unit are characterized by a finer clastic supply associated with small carbonate nodules, which become gradually more abundant upwards. Burrowing seems to be widespread throughout the middle and the upper parts of the unit, whilst the lower part, rich in pyrite, seems to be devoid of it.

The increase of sandy content in the upper part of the unit noted in the Spanboth Valley, representing a coarsening upwards megasequence, was also observed elsewhere by Fuchs (1982 a) and by Brookfield and Andrews–Speed (1982).

Thickness. In the southernmost outcrops of the middle Spanboth Valley, the Kangi La Fm. reaches a maximum thickness of 350–400 m. Fuchs (1981, 1982 a) indicates a thickness of 400–600 m in the Kangi La area. Kelemen and Sonnenfeldt (1981) mentioned a thickness of 1000 m for the area near Lingshed, however tectonic repetitions may occur in this area. Therefore the Kangi La Fm. appears thicker northwards and northeastwards where the carbonate beds of Maastrichtian age rich in benthic Foraminifera are missing. There, the Kangi La Fm. possibly spans the whole Maastrichtian (Fig. 5).

Age. Fossil content of this unit is poor. It consists of a fragment of Turrilitid collected in the middle part of the formation, of rare unidentified Belemnites and Bivalves, and of few small, size–sorted, benthic and planktonic Foraminifera, which occur in the upper part of the unit. Among the planktonic Foraminifera the species identified are *Pseudotextularia elegans* (Rzehak), *Heterohelix globulosa* (Ehrenberg), *Rugoglobigerina rugosa* (Plummer), *Globigerinelloides bollii* Pessagno, and a juvenile specimen of *Globotruncana*. Benthic foraminiferal assemblages are an admixture of forms from shallow– water (*Quinqueloculina*) and from outer–shelf to upper bathyal environments (*Lenticulina, Gavelinella* i. e.). Size–sorting and mixing from different environments suggest that fossils were transported downslope into the basin. The recorded benthic Foraminifera are suggestive of inferred paleodepth from 200 to 500 m (upper bathyal) or deeper for the upper portion of the unit (Sliter, 1977). Due to the poor fossil content the age of this formation could not be accurately established. However, the occurrence of *Pseudotextularia elegans*, together with turrilitid Ammonite, suggests that the Upper Campanian is represented in the upper part of the unit. Then, the Kangi La Fm. possibly spans the Santonian (?) and the whole Campanian, in agreement with the age suggested by the previous authors, although a younger age cannot be ruled out at the top.

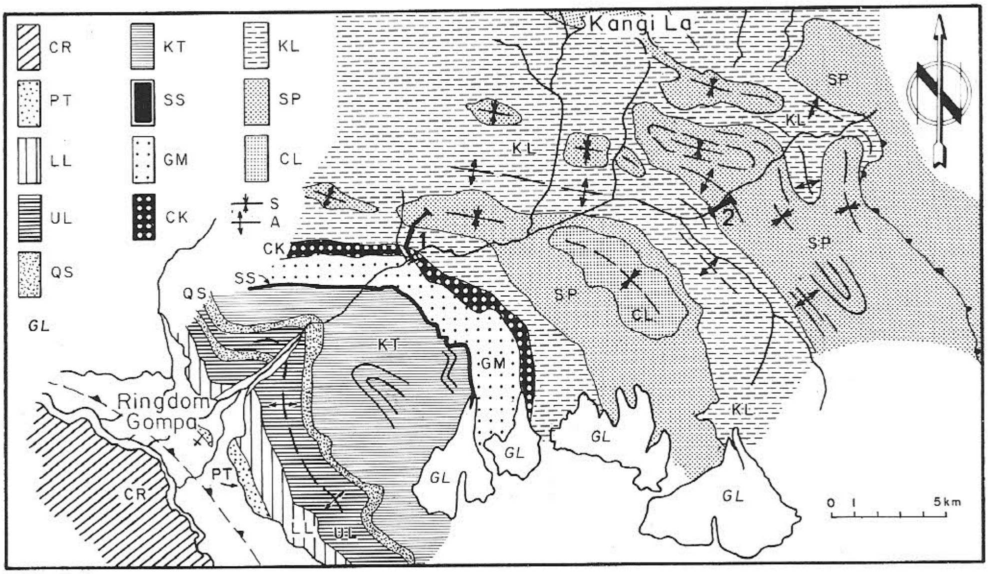


Fig. 2 – Geological sketch map of the Spanboth Chu Valley after our own data and Landsat picture. CR) Central Crystalline and Phugtal Nappe; PT) Panjal Traps; LL) Lower Lilang; UL) Upper Lilang; QS) Quartzite Series; KT) Kioto Group; SS) Spiti Shale; GM) Giumal Sandstone; CK) Chikkim Fm.; KL) Kangi La Fm.; SP) Spanboth Fm.; CL) Chulung La Slates; S) syncline; A) anticline; GL) glacier; 1) Spanboth Chu section; 2) Kangi Chu section.

Environment. The Kangi La Fm. of the middle Spanboth Valley may represent the distal part of a turbiditic fan complex, with coarser, sandy levels in the Kangi La area. The lower part instead, at least southwards, seems to be deposited in muddy, anoxic bottom conditions.

Spanboth Formation.

Name. Calcareous rocks of latest Cretaceous to earliest Cenozoic age are rare in Himalaya. As far as we know, they are recorded only from the Zebu Ri Syncline in Tibet (Kamba Dzong area, N of Qomolungma) (Hayden, 1907; Mu et al., 1973) and from the Zanskar. In 1982, Fuchs introduced the name of Spanboth Fm. for the rock unit which, in the Ringdom Gompa area, is comprised between the Kangi La Fm. at the bottom and the purple and green siltstones and shales at the top. The Spanboth Fm. can be subdivided in three distinct members: a lower member calcareous, randomly arenaceous, rich in *Omphalocyclus*; a middle member, predominantly arenaceous with subordinate or scanty carbonates; and an upper member, again calcareous, rich in *Daviesina*, very poor in terrigenous material. While the first two members display some similarities, the third one exhibits sedimentological character which may support to rise this unit to a formation rank in the future.

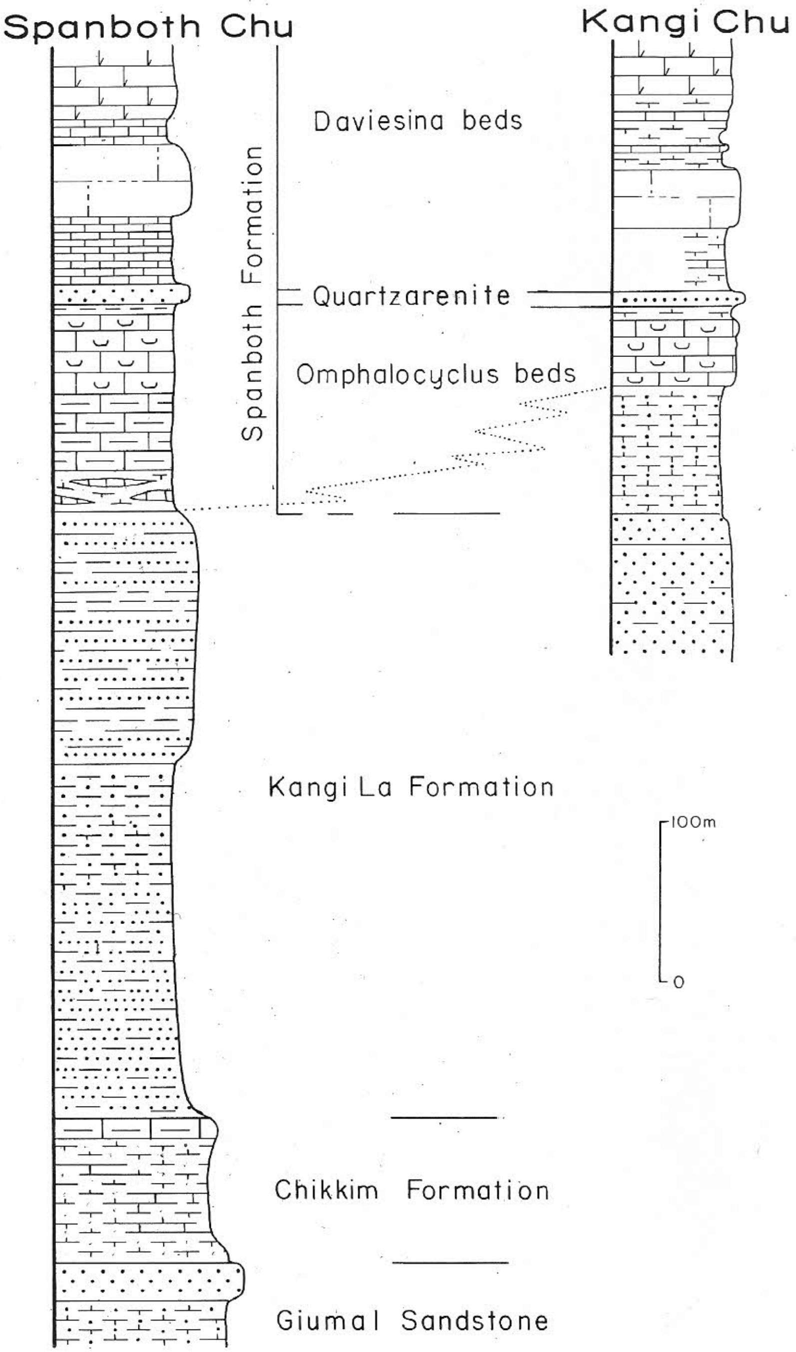


Fig. 3 – Correlations between the two sections measured in the Spanboth area from the Upper Cretaceous–Paleocene interval. Note the thicker *Omphalocyclus* beds and thus the early development of the carbonate sedimentation in the Spanboth Chu section, whilst in the Kangi Chu the clay and silt content is much higher.

Lower Member. The lower member consists of a fairly homogeneous sequence of grey to dark grey limestones, in beds 10 to 30 cm thick, somewhat nodular, with abundant *Omphalocyclus*, and a constant, abundant terrigenous content in the lower part. The contact with the underlying Kangi La Fm. is transitional and is marked by the appearance of skeletal carbonate grains within the quartzose siltite sequence.

The section was measured along the south crest facing the Spanboth Chu, starting at 4480 m a.s.l. (Fig. 2). This crest is shown on the left side of fig. 3 in Gaetani et al. (1980). From bottom to top:

1) grey calcareous siltites with small calcareous nodules. Rare thin beds of coarser quartzsiltite (HZ 116, 117); (17 m);

2) grey, dark marly limestones rich in bioclasts (mudstone/wackestone/floatstone) in «packed» beds 20 to 30 cm thick, alternating with thin–bedded siltites and marls (HZ 118, 119); (11.50 m);

3) grey limestones (packstone/wackestone) in beds 20 to 30 cm thick, very rich in Foraminifera, Crinoids, Corals, and calcareous Algae, associated with subordinate dense, poorly stratified limestones (mudstone/packstone) (HZ 120–134); (66 m);

4) dark–grey limestone (wackestone) with rare Foraminifera (HZ 135); (10 m);

5) dark–grey limestone (floatstone/wackestone, rarely packstone) in «packed» beds, 30–40 cm thick, locally rich in Corals (HZ 136–142); (14 m);

6) grey limestone (packstone/grainstone) in beds 30 cm thick, with intercalations of fissile marly limestone (mudstone/packstone) with sparse Foraminifera and Crinoids (HZ 143–145); (12 m);

7) grey marls with sparse small arenaceous lenses; rare Foraminifera. Poorly exposed (HZ 146, 147); (10.70 m).

The microfacies indicate frequent changes from mud–supported to grain–supported carbonates (Fig. 4). Wackestones prevail over floatstones. Occasionally packstones are present and grainstones scanty. Coated grains are rare, sorting is fairly good; bioturbation is common. Quartz associated with rare tourmaline is abundant at the bottom of the member, but both quartz and tourmaline decrease, then disappear, within the first 40 m of the sequence. Clay is scanty higher in the sequence except in the uppermost 15 m where the terrigenous material reappears. Foraminifera and Crinoid fragments are widespread throughout and sometimes very abundant, whilst Algae and Corals display a patchy distribution.

Sedimentological characters and fossil content suggest that the lower member was deposited in an infralittoral oxygenated environment along a carbonate ramp, where skeletal sands were buried fairly rapidly. The bottom was somewhat sheltered and never affected by strong currents.

Middle Member. The second member of the Spanboth Fm. is arenaceous, about 13 m thick. At the bottom it consists of a white, brown–weathered, coarse bedded, supermature to mature quartzarenite, 6 m thick (HZ 148, 149).

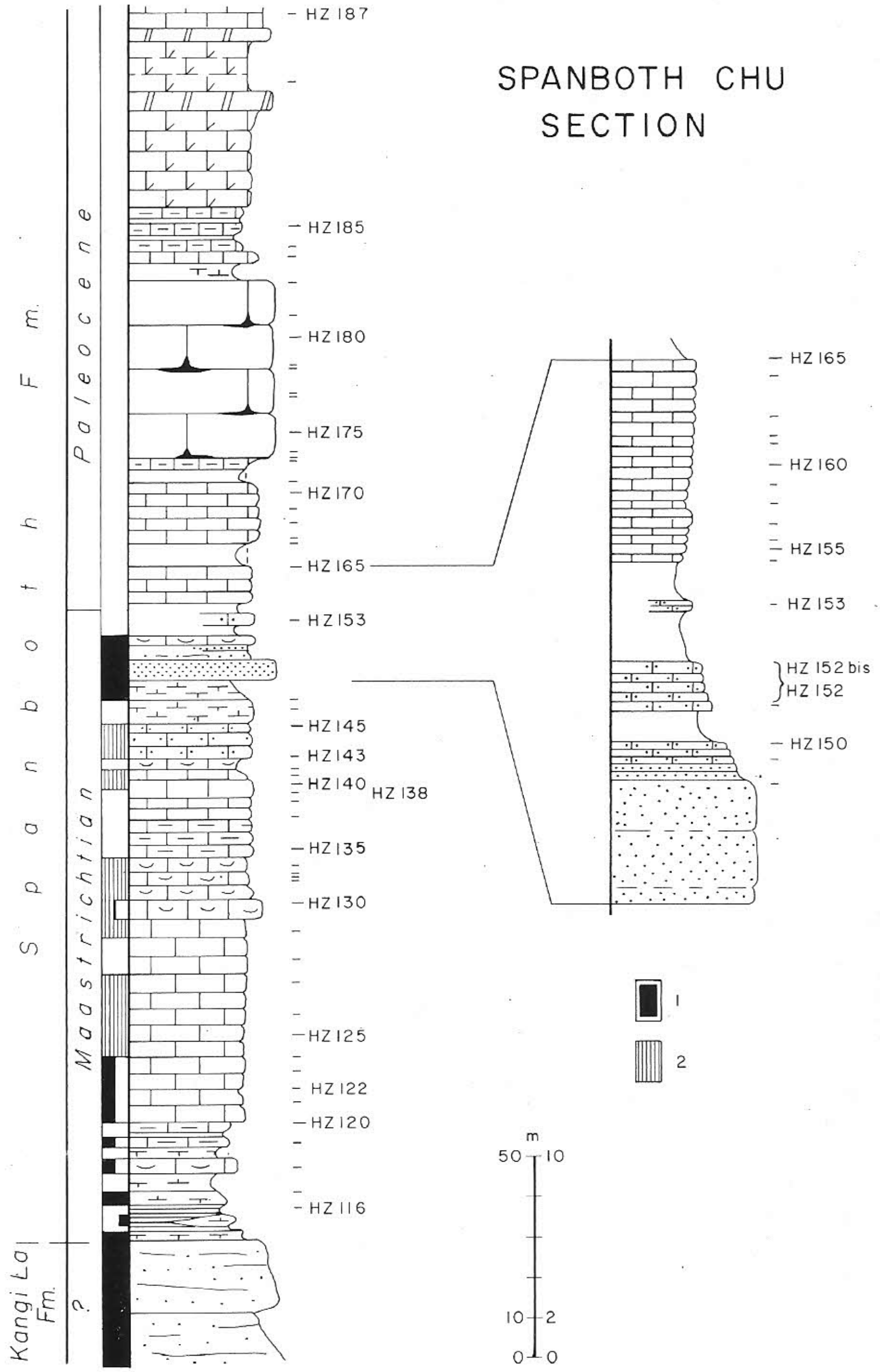


Fig. 4 – Spanboth Chu section, Spanboth Fm. 1) Terrigenous material. 2) Skeletal supported.

It is followed by a thin bedded, mature to submature, grey quartzarenite (HZ 150, 151) sometimes bioturbated, passing upwards into a grey–green, immature, quartzose calcarenitic sandstone (HZ 152, 152 bis, 153) with some lenses very rich in a single Oyster species (*Odontogryphaea morgani* (Vredenburg)). The upper part is poorly exposed. The contact with the third member is covered for more than a 3 m thick interval. This covered interval unfortunately contains the Cretaceous/Paleocene boundary.

From a sedimentological view point, the upper fossiliferous portion of this member appears to have been deposited under shallow, subtidal conditions. On the basis of the monospecific character of the Ostreid assemblage, somewhat restricted conditions of sedimentation may be inferred. The thick white quartzarenite instead does not contain any definite indication of marine environment.

Upper Member. This unit is characterized by dark grey limestones replaced by dolomite in the upper part. The unit is very poor in terrigenous content; locally is very rich in *Daviesina*. It is over 140 m thick.

The section was continued along the western side of the crest, then inside the canyon on the southwestern face, up to an altitude of 4650 m, where precise measurements were prevented by the disrupted beds in the core of the syncline. From bottom to top:

1) dark grey, bioturbated limestone (mudstone in the lower 10 m, then mudstone/wackestone, or floatstone) in slightly nodular, poorly defined beds. Recessive, poorly exposed (HZ 154–171); (30.6 m);

– not exposed (6 m);

2) dark grey limestone, cliff–forming, in beds 10–40 cm thick, very «packed», hard. Mostly wackestone with subordinate mudstone and packstone, or floatstone (HZ 172–182); (44.7 m);

3) laminated dark grey marls and marly limestones (mudstone) (HZ 183); (5 m);

4) dark grey laminated limestone extremely rich in *Daviesina*, in beds 10–15 cm thick; wackestone/floatstone with rhomboedra of dolomite (HZ 184, 185); (12 m);

5) dark grey limestone (wackestone) in beds 20–40 cm thick, with lenses of white dolomite, or in alternation with whitish dolomitic beds. Selective dolomitization also occurs in beds rich in Foraminifera (HZ 186, 187); (more than 44 m).

The microfacies of this unit is fairly homogeneous; skeletal grains are usually mud–supported. Foraminifera are very abundant, whilst sparse Crinoid fragments, Algae and solitary Corals appear in the middle to upper part of the sequence. This unit is interpreted to be deposited in a subtidal carbonate bay, sheltered from strong currents, with sufficient oxygen circulation and some terrigenous supply.

Age. The Spanboth Fm. is rich in age–diagnostic fossils. Although the age of the single members will be discussed in detail below, we can anticipate that the Spanboth Fm. spans the interval from Middle (?) and Late Maastrichtian to Late Paleocene. A gap spanning the great part of Early Paleocene occurs between the second and the third members. Moreover, the *Assilina* beds of Ilerdian age (latest Paleocene) are not reported so far from the Spanboth Valley.

Chulung La Slates.

The term was introduced by Fuchs (1982 a, b) to designate the «purple to green litharenite» of Gaetani et al. (1980). This unit ends the marine sequence in the Zanskar and according to Fuchs its age may be Eocene.

Nature of the terrigenous supply

The Early Cretaceous Giumal Sandstone and the Late Maastrichtian quartzarenitic member of the Spanboth Fm., the two stratigraphic units described from the W Zanskar, consist almost entirely of siliciclastics. Terrigenous material also occurs, to a lesser degree, in the Santonian (?)– Campanian Kangi La Fm. and in the lowermost 40 m of the Spanboth Fm. (lower member). The siliciclastic units are interbedded with units consisting mainly of carbonates (Chikkim Fm. and upper member of the Spanboth Fm.).

The petrographic composition of the topmost layer of the Giumal Sandstone is characterized essentially by quartz associated with some volcanic and shaly rock fragments, and rare feldspars (HZ 105). Afterwards, the siliciclastic supply decreases abruptly within a 50 cm thick interval, that marks the transition to the Chikkim carbonates.

Terrigenous material, mainly a quartz residue, constitutes also the immature, moderately well to well sorted coarse silt fraction distributed throughout the pelagic marly Kangi La Fm. (HZ 114, 115, 188a, b, H 21, H 22) in amount varying from traces to about half of the total sediment. Moreover, other siliciclastic components besides quartz occur in the upper part of the Kangi La and in the lower part of the Spanboth Fm. They consist of locally abundant biotite flakes, almost always completely altered to chlorite, and of small subhedral plagioclase grains, never exceeding a few percent of the total volume of the original sediment. Their occurrence could be interpreted as an indication of a coeval volcanic activity (HZ 188 a, b, H 21, H 22, HZ 116, HZ 123).

The lower part of the middle member of the Spanboth Fm. (HZ 148, 149) consists of a medium to fine grained, well sorted quartzarenite, cemented by syntaxial quartz overgrowths. Up to 99% of the grains are quartz. Most quartz is single with undulatory to segmented extinction common to both grains and cement and developed also after deposition. Quartz overgrowths interlock tightly, displaying a pressolved quartzitic texture (Skolnick, 1965). Very small (20 to 30 microns), unstrained new crystals have grown along the old crystals' sutured boundaries or even inside composite grains. These features testify to an intense post–depositional deformation (Conolly, 1965; Young, 1976) in conditions not very far from those of a truly metamorphic environment (Carter et al., 1964). These characteristics, however, are less evident or absent in the fine to very fine grained, more clay–rich samples of the upper part of the member.

The layers overlying the quartzarenite (HZ 150, 151, 152, 152 bis, 153) pass into well to poorly sorted sandstones with more abundant less stable grains and matrix. Probably some clay has been introduced in the sediments after deposition by burrowing activity. In the topmost layers of the middle member the intrabasinal influence becomes prominent once more, as testified by the occurrence of mainly allochemical carbonate grains (large fragments of Oyster–shells and Echinoids) and micritic mud.

In the arenaceous middle member of the Spanboth Formation, feldspars (chiefly orthoclase) and rock fragments are rare. Among the heavy mineral fraction zircon and particularly tourmaline are very abundant. Angular, only slightly altered hornblende, rutile and possibly sphene and epidote are also present.

Single quartz grains have quite often tourmaline inclusions; they likely derived, whether directly or indirectly, mainly from tourmaline–bearing pre–Himalayan granitoid bodies which are well known both in nearby areas (Frank et al., 1977; Honegger et al., 1982) and farther to the south in the Precambrian of the Indian Craton (Gansser, 1964). Some grains are very likely to be polycyclic (well rounded tourmaline and quartz), while a volcanic source is documented by a few felsitic rock fragments (Dickinson, 1970). Owing to petrographic observations performed also on samples from the Upper Triassic Quartzite Series and the Lower Cretaceous Giumal Sandstone, we can think about the Indian Continent to the south, with the basement complex of the Upper Precambrian or even Lower Paleozoic peneplaned ranges, and possibly the Gondwanian tillite deposits of Upper Paleozoic age, as the more likely source of the bulk of the siliciclastic detritus carried to the Tethys Himalaya shallow to moderately deep seas throughout the whole Mesozoic.

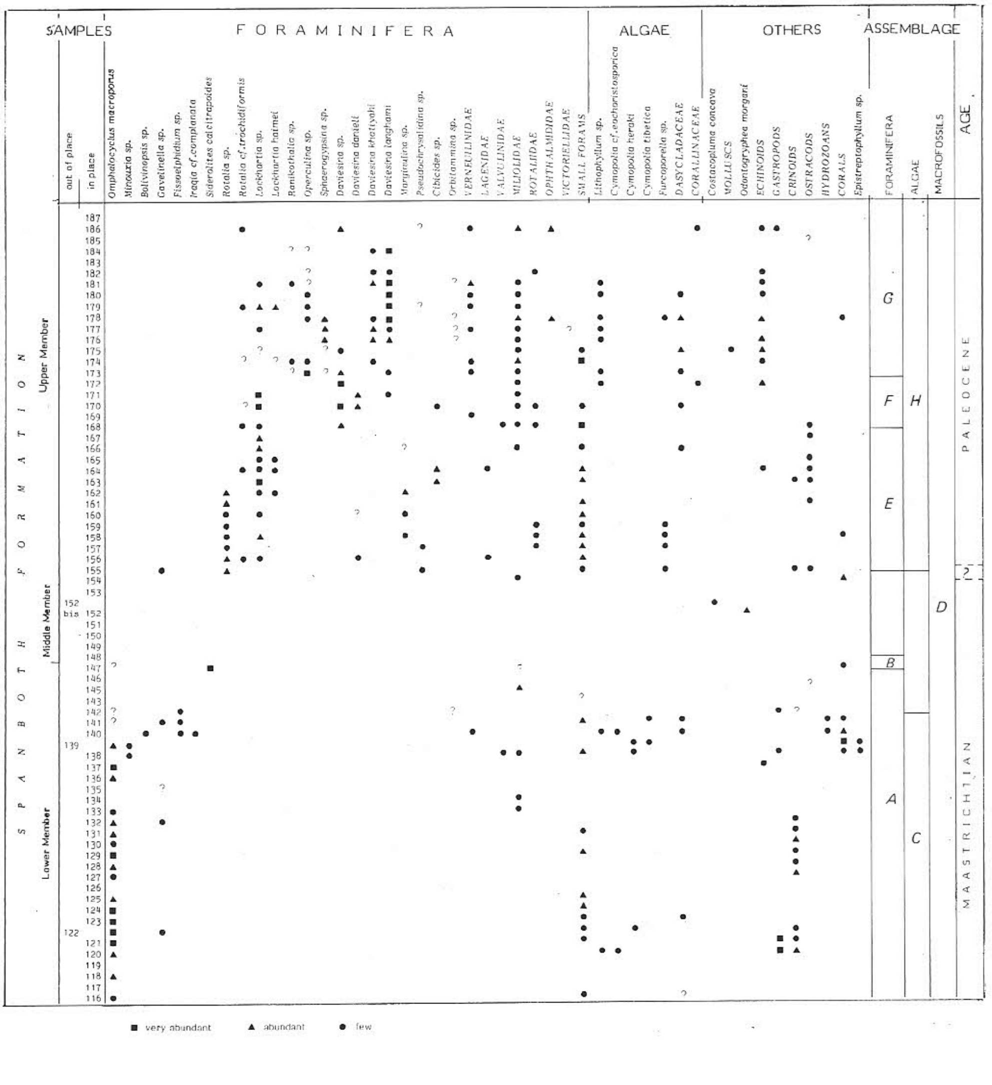
Biostratigraphy and Chronostratigraphy

Among the rock–units surveyed in the Spanboth section, the Spanboth Fm. is the most fossiliferous and yielded several age–diagnostic taxa. Then, biostratigraphic studies were focused on that unit from which 71 closely spaced samples have been collected.

The fossiliferous content consists of representatives from shallow–water benthic communities, such as small and larger Foraminifera, calcareous Algae, Corals, scanty Ostreids and one Crustacean. Benthic Foraminifera are the most abundant and display higher diversity in respect to the other groups. Five foraminiferal assemblages have been identified, two characteristic of Late Cretaceous and three of Late Paleocene age. Among the calcareous Algae the two identified assemblages, one Maastrichtian and a second one Paleocene in age, are dominated by the Dasycladaceans, while the Corallinaceans (*Lithophyllum* sp.) are rarer and distributed without any change throughout the interval.

The other groups are minor component and scattered throughout except the Ostreids which are concentrated in one horizon in the middle of the considered sequence where the only one Crustacean specimen was also found.

Stratigraphic distribution and estimated abundance of the various fossil components are plotted in Table 1. The recognized assemblages are as follows (roughly from bottom to top):



A – **Omphalocyclus macroporus Assemblage.**

In the Spanboth section the *Omphalocyclus* beds are characterized by an extremely monotonous faunal assemblage dominated by *Omphalocyclus macroporus* (Lamarck) whose specimens are poorly preserved, fragmented, often oriented essentially because of the methamorphism, associated with small Foraminifera (*Lagenidae*) that show a characteristic thin, black outline, rare Algae (see assemblage C), Corals (*Epistreptophyllum* sp.) and Crinoids. In the upper portion of the *Omphalocyclus* beds (HZ 140, 141, 142) rare, mostly recrystallized *Fissoelphidium* sp. have been found.

B – **Siderolites calcitrapoides Assemblage.**

This assemblage is very poor and characterized by recrystallized fragments of *Siderolites calcitrapoides* Lamarck and few fragmented *Omphalocyclus macroporus* (Lamarck). It is confined to sample HZ 147.

C – **Cymopolia Assemblage.**

The oldest algal assemblage (from HZ 120 to sample HZ 141) consists of badly preserved thalli of *Cymopolia eochoristosporica* Elliott and forms related to this group, of *Cymopolia heraki* Gusic and *Cymopolia* cf. *tibetica* Morellet.

D – **Odontogryphaea Assemblage.**

This assemblage is monospecific. *Odontogryphaea morgani* (Vredenburg) occurs concentrated in lenses mainly with fragmented and deeply recrystallized single valves.

Few meters above the Oyster–rich lenses a single specimen of the Crab *Costacopluma concava* Collins & Morris was also found.

E – **Lockhartia–Rotalia Assemblage.**

The two index genera largely dominate the microfauna (from sample HZ 155 to sample HZ 168) with well preserved and abundant specimens. They are associated with small Foraminifera (*Marginulina* sp., *Dentalina* sp.), Ostracods and rare Algae (see assemblage H). In samples HZ 156 and HZ 160 rare small forms have been doubtfully attributed to *Daviesina danieli* Smout.

F – **Daviesina–Lockhartia Assemblage.**

This assemblage is characterized by the constant, common occurrence of *Daviesina*. Poor preservation prevented identification at specific level except in HZ170 and HZ171 where rare specimens, even badly preserved, could be attributed to *Daviesina danieli* Smout. Common forms in this interval are *Lock-*

hartia (*L. haimei* (Davies)), *Rotalia* (*R.* cf. *trochidiformis* Lamarck, *Rotalia* sp.), Miliolids and Verneuilinids, and some Ostracods. In HZ 171 *Daviesina langhami* Smout first appears, but its record is still scattered.

G — **Daviesina langhami—Daviesina khatiyhai Assemblage.**

This assemblage occurs in the upper part of the sequence from sample HZ 173 till the top. In the lower part of this interval (HZ 173, 174) the assemblage is characterized by very abundant *Operculina* sp., associated with rare «*Sphaerogypsina*» sp. and *Daviesina langhami* Smout (HZ 173), and rare *D. khatiyhai* Smout and *Ranikothalia* sp. in HZ 174. In this part also, several specimens of *Daviesina* are recorded, but the bad preservation of the fauna, that is often squashed and oriented due to the methamorphism, prevented identification at specific level. From sample HZ 176 upwards the two nominal species of *Daviesina* become frequent with *D. langhami* Smout dominating over *D. khatiyhai* Smout, much rarer.

In the middle part of this assemblage «*Sphaerogypsina*» sp. is very common (HZ 176, 177, 178). *Lockhartia* sp. is still present in sample HZ 179, and 181, and in HZ 179 it dominates the fauna. In HZ 181 rare *Ranikothalia* sp. are recorded. Miliolids, *Verneuilinidae,* Echinoids, calcareous Algae (see assemblage H), Corals are also present but with few specimens.

H — **Furcoporella Assemblage.**

The second, younger algal assemblage (from sample HZ 155 to the top of the section) shows a complete change in the flora which is dominated by *Furcoporella* sp., probably *F. diplopora* Pia (the strong recrystallization prevents specific identification) and few specimens of *Cymopolia* sp.

Discussion

It is worth mentioning that the Cretaceous/Tertiary boundary was placed between the Middle and the Upper Member of the Spanboth Fm. However, neither the last sample of the Middle Member (HZ 153) nor the first one of the Upper Member (HZ 154) yielded age—diagnostic fauna. The first sure Paleocene organisms occur in sample HZ 155.

Comparisons between the assemblages mentioned above and those described from the Kangi Chu section (Gaetani et al., 1980) outcropping about 15 km to NE, suggest the following remarks:

a) the foraminiferal assemblages have been already recognized except for assemblage E;

b) the *Omphalocyclus* beds in both sections are characterized by a poorly diversified, dominantly monospecific faunas (*Omphalocyclus macroporus* (Lamarck)). Among the small benthic Foraminifera, often very abundant, Lagenids are the most frequent;

c) *Siderolites*, characterizing the Assemblage B, is rare and recorded essentially as recrystallized fragments in the Spanboth section. On the contrary, in the Kangi Chu section *Siderolites calcitrapoides* Lamarck was very abundant and particularly well preserved;

d) the *Odontogryphaea* assemblage was not recorded from the Kangi Chu section. Possibly this layer was not noted because of the poor exposure of the upper part of the Middle Member of the Spanboth Fm., or because of lack of lateral continuity of the Oyster level;

e) in the Spanboth section, the *Daviesina* assemblages are very rich in specimens, but preservation is so poor that frequently prevented identification at specific level; this is particularly evident in Assemblage F;

f) the absence of assemblage E not recorded in the Kangi Chu section, according to us, is apparent and related only to poor sampling of the corresponding interval;

g) new finding is the abundant occurrence of *Operculina* with well preserved specimens in the lower part of Assemblage G. In the Kangi Chu section, only one fragment of *Operculina* was found in the underlying *Daviesina danieli* assemblage (= Assemblage F). Representatives of *Ranikothalia* are very rare instead in both sections;

h) concerning the calcareous Algae, it is worth mentioning that the Kangi Chu section displayed a richer Late Cretaceous algal assemblage than the Spanboth section. Slightly different paleoecologic conditions or accumulation may be accounted for the more numerous and differentiated algal tests with dominant Dasycladaceans (abundant *Cymopolia tibetica* Morellet and forms related to the group of *Cymopolia eochoristosporica* Elliott). Algal material from the Kangi Chu section was re–examined and descriptions of the two species identified are included in the paleontological appendix. On the contrary, the Paleocene algal assemblage is better represented, although strongly recrystallized, in the Spanboth section. Indeed, in the Kangi Chu section, may be because of poor sampling, Dasycladaceans were not recorded from Paleocene layers.

The foraminiferal Assemblages A and B were attributed to the Late Maastrichtian by Gaetani et al. (1980, p. 138). According to the literature (Gusic, 1967; Elliott, 1968; Bassoullet et al., 1978; Tibetan Sc. Expedition, 1975) floral Assemblage C is characteristic of the Maastrichtian, then the age based on Foraminifera is in agreement with the age indicated by Calcareous Algae. It is worth mentioning that *Cymopolia eochoristosporica* Elliott and *C. tibetica* Morellet are species typical of the Middle East and Himalayan regions, while *C. heraki* Gusic, up to now, has been recorded only from Yugoslavia (Bosnia) (Gusic, 1967). About the larger Foraminifera it is a peculiarity of the Spanboth section, as it was already of the Kangi Chu section, the monospecific character of the Assemblages A and B, the *Omphalocyclus* and *Siderolites* assemblages respectively. Important species belonging to the genera *Orbitoides* s.s. and *Lepidorbitoides* are missing in both sections even if representatives of both genera are recorded from this Asian region associated with either *Omphalocyclus* or *Siderolites* or both (Dilley, 1973; Gorsel, 1978).

In Gaetani et al. (1980) it was suggested that *Orbitoides* s. s. were missing in the Kangi Chu section because 1) the *Omphalocyclus* beds were younger than the extinction level of Orbitoids (Middle ? to Late Maastrichtian) and 2) the underlying Kangi La Fm. was deposited in a pelagic environment, too deep for the shallow–water Orbitoids. The same hypothesis could apply to their absence in the Spanboth section. On the other hand, Gaetani et al. (1980) also stated that the representatives of the genus *Lepidorbitoïdes,* which ranges as high as the topmost Maastrichtian, might be missing because of unfavorable environmental conditions. Then, such unfavorable environment could also have prevented the Orbitoids to migrate into the Spanboth area.

Regional Paleogeography: discussion of data and preliminary interpretation

Discussion of data.

The rapid increase of the geological knowledge in Ladakh, south of the Indus River, makes now possible to outline, although in a preliminary and somewhat general draft, the stratigraphic scheme of the Cretaceous and Paleocene of the Zanskar area, both west and east of the Zanskar River (Fig. 5) (Fuchs, 1979, 1981, 1982 a, b; Srikantia & Razdah, 1979; Srikantia et al., 1980; Gaetani et al., 1980; Kelemen & Sonnenfeldt, 1981; Baud, Arn et al., 1982; Bassoullet et al., 1982). The discussion below deals in particular with the sequences south of the Indus Suture Zone, that is to say those belonging to the Shillakong, Zanskar, and High Himalaya Nappes (Fig. 1, 2). It should be taken into account that we consider the Upper Kong Valley and the surrounding of Lingshed as belonging to the High Himalaya (= Tibetan Zones of Fuchs) and not to the Northern Zanskar Unit as suggested by Fuchs (1982 a, b).

East Zanskar area.

Zanskar Nappes. The Cretaceous succession of the Zanskar Nappes is illustrated in the paper by Baud, Arn et al. (1982). According to those Authors, the Zumlung Unit is composed of about 40 m of Early Cretaceous Giumal Sandstone, overlain by the Chikkim Fm., which spans the interval from Late Albian to Turonian–Coniacian. The Chikkim Fm. consists of well bedded, grey marly limestones, more than 200 m thick, and includes a distinctive arenaceous episode of Middle Cenomanian age. The post–Coniacian sequence was not studied.

High Himalaya Nappes. In the Zangla Unit the thickness of the Giumal Sandstone exceeds 150 m, i. e. more than three times thicker than in the Zumlung Unit. The few samples from the Giumal Sandstone we collected near Zangla lack of fossils. It is possible that the uppermost part of the exposed sequence belong to the Kangi La Fm.

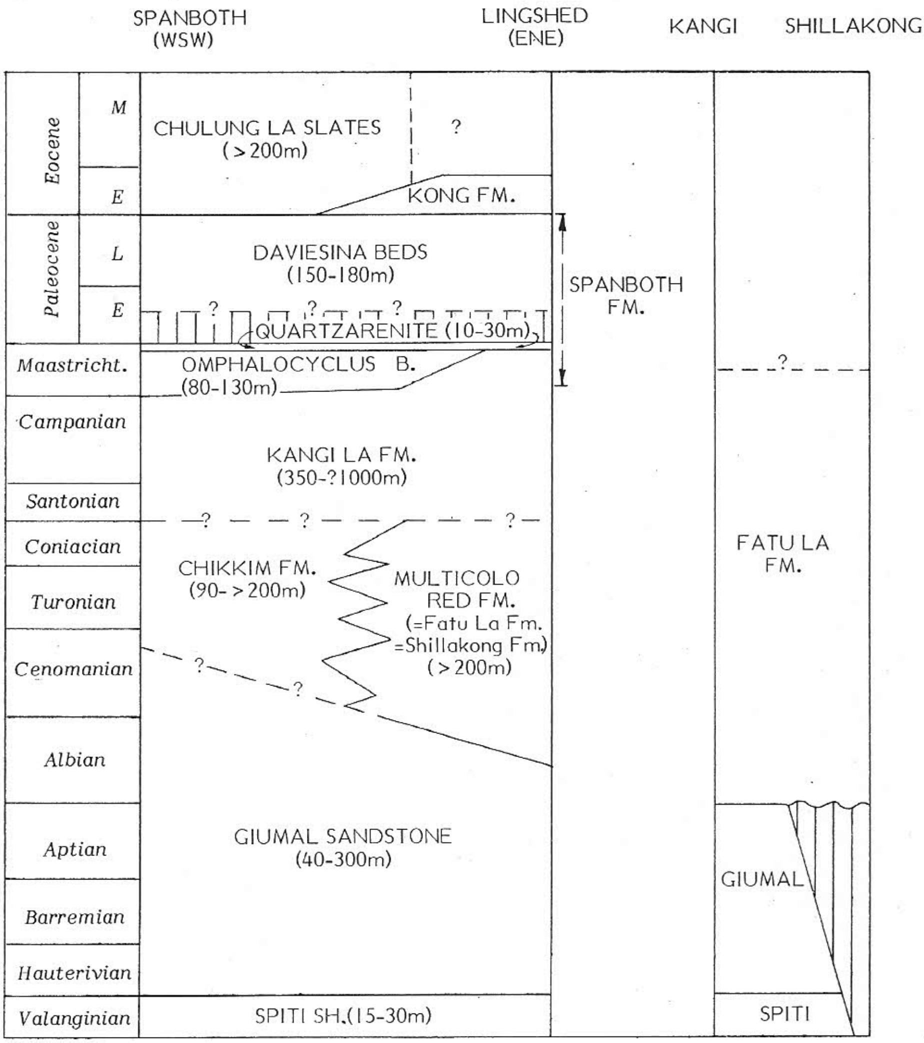


Fig. 5 – Stratigraphic sketch of the Cretaceous–Tertiary units with tentative correlation between the Zangla Nappe (= High Himalaya or Tethys Himalaya) and Shillakong Nappe. Vertical lines = hiatus.

The two hypothesis, concerning the Orbitoid absence (see p. 96), imply a different age of the top of the Kangi La Fm., then consequently of the overlying *Omphalocyclus* beds. In the first case, the Kangi La Fm. might be as younger as the Middle Maastrichtian and the *Omphalocyclus* beds are only Late Maastrichtian in age. In the second case, on the contrary, a generic Maastrichtian age should be attributed to the *Omphalocyclus* beds, while the top of the Kangi La Fm. cannot be dated more precisely than a generic Late Campanian – possibly Early Maastrichtian.

The occurrence of *Lockhartia* without *Daviesina* in the lowermost sample (Assemblage E) above the covered interval in the Spanboth section dates the base of the upper member of the Spanboth Fm. as the late Early Paleocene. The overlying layer containing rare specimens of *Daviesina,* possibly *D. danieli,* must be dated as Middle Paleocene (Smout, 1954; Gaetani et al., 1980). Representatives of the genus *Daviesina* (*D. khatiyhai* and *D. langhami*) persist till the top of the marine sediments recovered from the Spanboth section. Then the *Daviesina* beds from this section as well as from the Kangi Chu section predate the Ranikot Limestone of Late Paleocene age (Adams, 1967).

This interpretation is confirmed by the scarcity of *Ranikothalia* (one specimen in sample HZ 174) and the lack of other larger Foraminifera of Late Paleocene age in both sections.

Finally, according to the literature (Massieux, 1966; Elliott, 1968; Tibetan Sc. Expedition, 1975), the flora of Assemblage H is typical of the Paleocene and Eocene of Middle East and of the Middle Eocene of Central and Southern Europe, in agreement with the age based on benthic Foraminifera.

West Zanskar.

Shillakong Unit. The Cretaceous succession in this unit is represented by the Fatula Fm. (Bassoullet et al., 1982) (= Multicolored Limestone) dated as Late Aptian/Early Albian to Campanian. The Fatula Fm. rests unconformably on the Late Jurassic–? Early Cretaceous Spiti Shale, and in the most northern part, on the Kioto Group of Early to Middle Jurassic age. Conversely, in the southernmost area of the Shillakong Nappe, the Giumal Sandstone is interbedded between the Spiti Shale (below) and Fatula Fm. (above).

Zangla Unit. In this unit, Late Cretaceous to Paleocene sequence is known from the Lingshed area and from the Spanboth–Kangi La area, described in the previous chapter.

Lingshed area. Late Cretaceous–Tertiary terranes from the Lingshed area were described by Kelemen and Sonnenfeldt (1981) and Fuchs (1981, 1982 a, b). According to Fuchs (1981, 1982 a, b), the stratigraphic sequence (from top to bottom) is as follows:

« – Kong Slates: cream, light grey to greenish slates with few beds of blue grey limestone. Thickness of about 100 m; mostly Early Eocene. (The age is based on the occurrence of *Assilina, Nummulites, Alveolina* which, however, were collected in the Kong area and not in the Lingshed area. Present author's opinion).

– Lingshet Limestone: blue dark grey, partly cherty limestone followed upwards by blue–black limestone and light grey dolomitic limestone. Minor occurrence of quartzite and sandy limestone at the base. Thickness of some 150 m. Late Paleocene in age, with rich Foraminifera content (*Alveolina, Lockhartia, Orbitolites*).

– Lamayuru Formation (Maastrichtian portion): dark grey to black slates and silty slates. Rarer micaceous sandstones. Thickness of several hundred meters. Planktonic Foraminifera (*Globotruncana stuarti, Globotruncana arca*) were recovered.

– Shillakong Fm. (= Multicolored Fm.): white, grey, red and green limestone and shales. Thickness of several hundred meters, Late Cretaceous.»

In our opinion the Lingshed stratigraphy could be re–interpreted as follows (from top to bottom):

Fuchs (1982 a, b)	present paper
Kong Slates	Kong Slates
Lingshet Limestone	(?) Middle & Upper Members of Spanboth Fm.
Lamayuru Fm.	Kangi La Fm.
Shillakong Fm.	Fatula Fm. or Multicolored Fm.

Preliminary interpretation.

Although further studies are needed in order to better understand the relationships of the different stratigraphic/tectonic units, the depositional history of the area of investigation for the Cretaceous through the Paleogene time–interval can be delineated tentatively as follows.

During the Mesozoic time the Indian continent was exposed to the south of the investigated area, which was located at the northern margin of the continent, facing the open sea to the north. The Indian continent was likely the source–area of the bulk of the siliciclastics supplied to the shallow to moderately deep sea of the Tethys Himalaya, as supported by the petrographic analysis of the Late Triassic Quartzite Series, and of the Cretaceous formations (Giumal Sandstone, Kangi La Fm., Middle Member of the Spanboth Fm.). Most of the Early Cretaceous was a time of highly terrigenous deposition (Giumal Sandstone) widespread in the whole area, except in the northern Shillakong Unit, where a large unconformity occurs.

By the early Late Cretaceous (possibly post–Cenomanian through Coniacian) the studied portion of the Indian continental margin was the site of a dominantly open–marine, pelagic deposition as testified by indurated pelagic ooze, the Chikkim Fm. and related facies (Multicolored Fm., Fatula Fm.)

(Fig. 5). The crude estimated sedimentation rate for those units does not exceed 20 m/my.

By the Santonian continuing through the Campanian, large amount of primarily silty and clayey, sometimes sandy, terrigenous material was introduced into the pelagic basin. Such an admixture of pelagic and terrigenous components characterizes the Kangi La Fm., which was deposited at an estimated rate as high as 40 to 50 m/my. The main source of the terrigenous supply of the Kangi La Fm. was the Indian Craton, as it was during deposition of the older Giumal Sandstone.

By Maastrichtian time (possibly Middle to Late Maastrichtian) the terrigenous input largely decreased and carbonate sedimentation dominated the

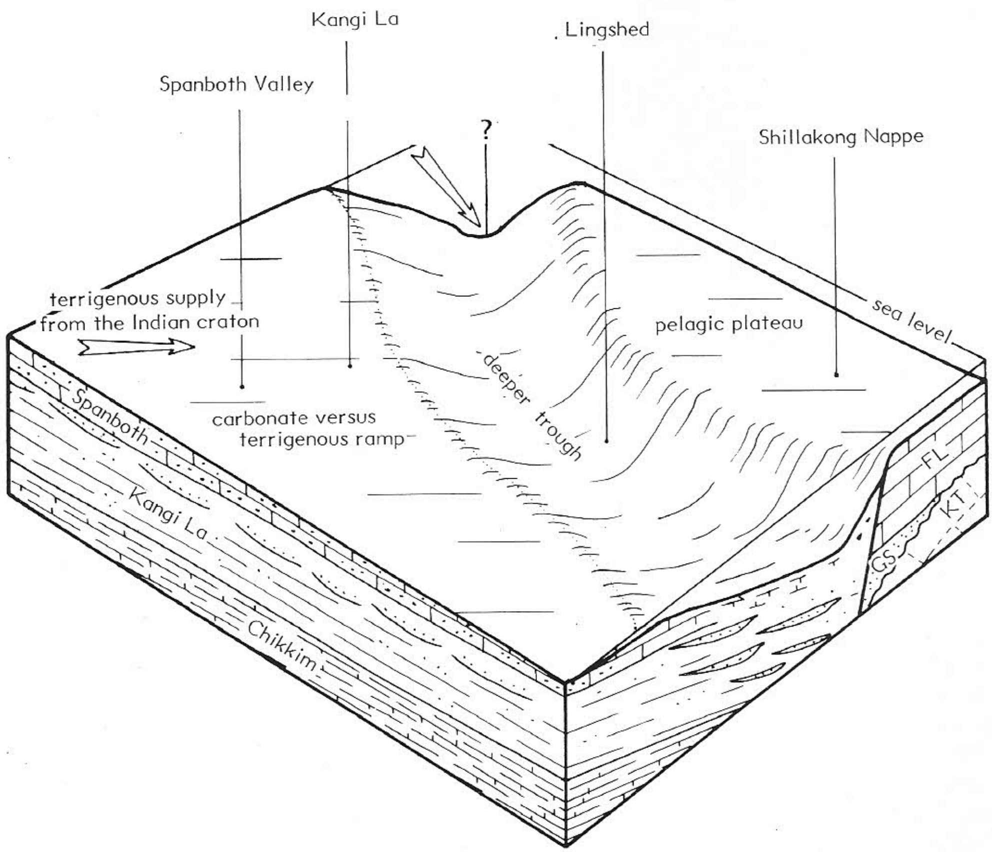


Fig. 6 – Tentative paleogeographic reconstruction of the continental margin of the Indian plate in Zanskar at Maastrichtian time. Note that up till now Maastrichtian sediments are not reported from the Shillakong Nappe, which is interpreted as a location of a pelagic like plateau during the Late Cretaceous, including the Maastrichtian. At the end of the Cretaceous in that area terrigenous material is absent and the sedimentation rate is very low.

whole area. However, in the Spanboth area, carbonates are characteristic of a shallow–water environment, specifically of a carbonate ramp to even shallower marine environment, which was polluted periodically with a minor amount of terrigenous material derived from the Indian Craton. The Lower Member of the Spanboth Fm. was deposited at a sedimentation rate probably still exceeding 40 m/my, as the underlying Kangi La Fm.

At the same time, towards the north and the northeast, sediments became also richer in carbonate, but they were deposited still in an open marine, deeper pelagic environment as testified by the occurrence of Maastrichtian planktonic Foraminifera (Fuchs, 1982 a). At the site of deposition of such pelagic sediments, Brookfield and Andrews–Speed (1982) identified a foredeep of the Indian continental margin. According to our reconstruction shown in Fig. 6, Fuchs' Lamayuru Fm., Maastrichtian in age (1981, 1982 a, b) represents a distal, more pelagic facies of the youngest part of the Kangi La Fm. as well as of the *Omphalocyclus* beds of the Spanboth area.

A distinctive regressive episode occurred near the top of the Cretaceous. On the basis of our interpretation this episode could be correlatable with the world–wide sea level drop recorded during Late Maastrichtian time (Vail et al., 1977) and may not be the result of a regional tectonic uplift. The quartzarenite level, whose clastics derived from the Indian Craton, could represent, on the basis of its texture and shape, a littoral marine deposit, but evidence is not conclusive. In places, the quartzarenite is followed by terrigenous, very shallow, sublittoral deposits of Maastrichtian age. These littoral to sublittoral sediments are stratigraphically represented by the Middle Member of the Spanboth Fm. In our interpretation they are correlative and markedly coeval of the «rusty–weathered quartzite beds» considered by Fuchs (1982a) as the heterochronous base of the Lingshet Limestone.

Most of the Early Paleocene seems to be missing. Unfortunately, part of the sequence at the Cretaceous/Tertiary boundary in both measured sections is covered and the nature of the gap in between could not be investigated. By the end of the Early Paleocene, sedimentation resumed, with carbonate sediments possibly being deposited in a quiet, shallow water environment at an apparent sedimentation rate of about 30 m/my. The calcareous part of Fuchs' Lingshet Limestone (1982 a, b) seems to be correlatable with this Upper Member of the Spanboth Fm.

At the top of the Spanboth Fm., a continental terrigenous unit developed, the Chulung La Slates (Fuchs, 1982 a). Northwards, in the Kong area, the continental beds of the Chulung La Slates interfinger with marine sediments, named Kong Slates by Fuchs (1982 a). They contain the Eocene fauna described by Metzeltin and Nicora (1977) and quoted by Fuchs (1977, 1979, 1982 a). It is worth mentioning that the Kong Slates have been deposited at a site which coincides to the location of the foredeep of the Indian continental margin as identified during the Late Cretaceous. No younger marine sediments are known from the High Himalaya and Zanskar Nappes.

Paleontological appendix

Four species are described in this chapter. Three of them belong to the Dasycladacean Algae, i. e. *Cymopolia heraki* from the Spanboth section, *C.* aff. *eochoristosporica* and *C. tibetica* from the previously described Kangi Chu section (Gaetani et al., 1980). The fourth species belongs to the Crustaceans: it is the Crab *Costacopluma concava*, also from the Spanboth section.

No paleontological descriptions of large Foraminifera are included in this paper because of the poor to very poor preservation of the specimens recovered in the Spanboth section. However, the same foraminiferal species were described from the Kangi Chu section in the paper by Gaetani et al. (1980) which the reader can refer to.

Phylum C H L O R O P H Y C O P H Y T A Papenfuss, 1946

Class CHLOROPHYCEAE Kützing, 1843

Ordo **Dasycladales** Pascheer, 1931

Family *D a s y c l a d a c e a e* Kützing, 1843

Tribe *N e o m e r e a e* Pia, 1920

Genus *Cymopolia* Lamouroux, 1816

Cymopolia heraki Gusic, 1967

Pl.8, fig. 9; Pl. 9, fig. 1

1967 *Cymopolia heraki* Gusic, p. 118–121, pl. 1–3.

Material: Thin sections HZ 122, HZ 138.

Diagnosis. Cylindrical thallus with short primary branches and four longer secondary branches developing from a globular sporangium.

Description. Long (some 6 mm), regular calcified cylindrical thallus with subrounded ends. Branches are tubular and perpendicular to the central cavity; primary branches are very short (the 30% of the wall wideness) and swollen in a globular sporangium from which elongated secondary branches develop. Secondary branches show a funnel shaped ending.

Dimensions (in mm) (1):

D = 1.25–0.87	d/D % = 40%
d = 0.5 –0.37	
s = 0.35–0.25	
h = 0.18–0.12	
l_1 = 0.05	l_2 = 0.17

Remarks. The general characters fit perfectly with the description of Gusic (1967) except for that the globular sporangia appear to be a constant character of the specimens from the Spanboth section.

Age and distribution. ?Late Maastrichtian. *C. heraki* was previously recorded only from its type–locality in Bosnia in the Middle Maastrichtian (Gusic, 1967).

Occurrence. Spanboth section: Lower Member of Spanboth Fm. (= *Omphalocyclus* beds). Zanskar Range, Western Himalaya.

Cymopolia aff. **eochoristosporica** Elliott, 1968

Pl. 7, fig. 1–7; Pl. 9, fig. 2, 3

Material. Thin sections H 7A, H 7C, H 7b2, H 7D, H 7b1, H 7b3, H 16A, H 16B, H 16D, HZ 140.

Diagnosis. Cylindrical thallus with short primary branches with a swollen distal portion (rounded rectangular section, radially elongated) from which a sphaerical sporangium and four secondary branches develop.

Description. Long (up to 6 mm) cylindrical thallus, in one section club–shaped (H 7b2, Pl. 7, fig. 4). Very short (0.03 mm in average) primary branches with swollen, strongly elongated distal portion, giving rise to a sphaerical badly recognizable sporangium and four tubular secondary branches, generally badly preserved.

Dimensions (in mm):

D = 2.0 – 4	p = 0.13 – 0.22
d = 1.0 – 1.5	L = 0.32 – 0.75
d/D = 37%– 50%	p/L = 22% – 46%

(1) D) outer diameter
d) inner diameter
s) thickness of the wall
p) width of the swollen part of primary branches.
L) length of the swollen part of the primary branches
h) distance between two consecutive whorls
l_1) length of primary branches
l_2) length of secondary branches

Remarks. The specimens from the Spanboth Fm. differ from the typical *C. eochoristosporica* Elliott (1968, pp.40–44 pl. 9, fig. 1–3) for the dimensions much more elongated of the swollen part of primary branches. Moreover, in *C.* aff. *eochoristosporica*, the size–range of the swollen primary branches (p/L 22% – 46%) is wider than in Elliott's species. Further studies on other material will clarify if such a large range is a character that may be related to the specific variability of *C. eochoristosporica* Elliott (1968) which thus could include also the Spanboth's specimens. For the time being, we prefer to keep separate the two forms.

Age and distribution. *C. eochoristosporica* is recorded from Maastrichtian of Trucial, Oman (Arabian Peninsula) and Tibet.

Occurrence. Kangi Chu and Spanboth sections: Lower Member of Spanboth Fm. (= *Omphalocyclus* beds). Zanskar Range, Western Himalaya (Gaetani et al., 1980).

Cymopolia tibetica Morellet, 1916

Pl. 7, fig. 3, 4, 8; Pl. 8, fig. 1–8, Pl. 9, fig. 4,7

1916 *Cymopolia tibetica* – Morellet, p. 47, pl. 15, fig. 10; text–fig. 14–21.
1968 *Cymopolia tibetica* – Elliott, p. 41, pl. 8, fig. 3–4
1975 *Cymopolia tibetica* – Tibetan Scientific Expedition, part II, pl. 6, fig. 2–5.
1978 *Cymopolia tibetica* – Bassoullet et al., p. 82, pl. 25, fig. 3, 4.

Material. Thin sections H 7b2, H 7b3, H 8A, H 8B, H 8C, H 15A, H 16A, H 16C, H 16D, HZ 141.

Diagnosis. Cylindrical thallus with a very short primary branch with a swollen distal portion vertically elongated with rounded–rectangular section giving rise to a sphaerical sporangium and four secondary branches.

Description. Long (up to 7 mm), regularly calcified cylindrical thallus. Very short primary branches, perpendicular to the central cavity, with an expanded distal portion, rounded–rectangular in vertical section; from the swollen portion a sphaerical sporangium develops together with four elongated secondary branches with funnel shaped end.

Dimensions (in mm):

D = 1.1 – 1.7	p = 0.18 – 0.25
d = 0.6 – 0.9	L = 0.7 – 0.15
d/D = 55%– 57%	p/L = 40% – 60% mainly 50%

Age and distribution. ? Late Maastrichtian. *C. tibetica* is recorded from the Maastrichtian of Tibet, Turkey and Irak (Elliott, 1968).

Occurrence. Kangi Chu and Spanboth sections: Lower Member of Spanboth Fm. (= *Omphalocyclus* beds). Zanskar Range, Western Himalaya (Gaetani et al., 1980).

Phylum A R T H R O P O D A

Order Decapoda

Infraorder Brachyura

Superfamily *O c y p o i d e a* Rafinesque, 1816

Family *R e t r o p l u m i d a e* Gill, 1894

Genus *Costacopluma* Collins & Morris, 1975

Costacopluma concava Collins & Morris, 1975

Fig. 7 nel testo

1975 *Costacopluma concava* Collins & Morris, p. 823, pl. 97.

Remarks. The only specimen recovered is an internal mould of the carapace with traces of the legs. A little transverse deformation took place. The carapace is transversely oval and is 22 mm long and 12.5 mm wide. The size of the specimen fits well in the range of the species, even if the length is much less than two–third the greatest width, giving to the carapace a more elongated outline.

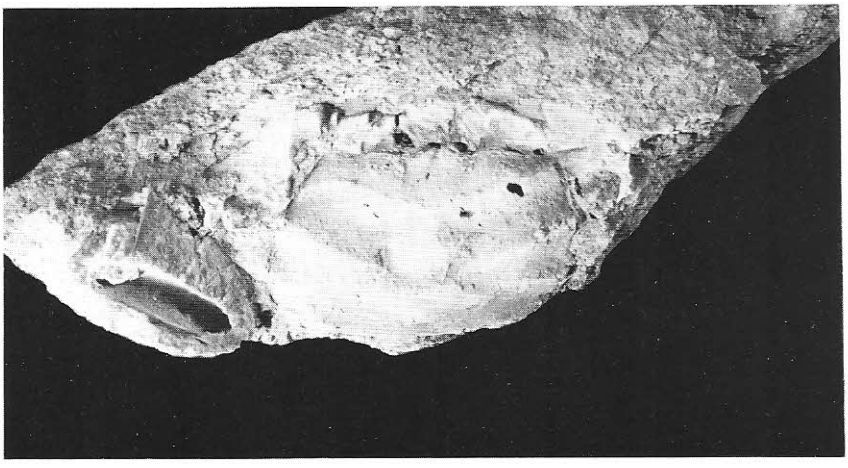


Fig. 7 – *Costacopluma concava* Collins & Morris, 1975. HZ 152 bis, Spanboth Chu section; x 2. Repository number 4108.

The three typical transverse ridges, as well as the two elongated tubercles on the metabranchial lobes are very similar in position and size to those of the type material. They are only more sharp and less detailed, but this is surely due to preservation. For example the cardiac portion of the third ridge appears as a regular ridge without the four tubercles described by Collins and Morris (1975). No traces of pits or small tubercles are present.

Age and distribution. *Costacopluma concava* was described only from the Upper Cretaceous (Coniacian – ?Maastrichtian) of Nigeria.

Occurrence. Spanboth section: sample HZ 152 bis, not in place at the top of the Middle Member of the Spanboth Formation. Zanskar Range, Western Himalaya.

Note added in proofs.

After this paper was submitted, we received the paper by Ganesan T. M., Razdan R. K., Razdan M. L., Muthu V. T. (1981) – Stratigraphy, Structure and Geological History of the Zanskar Basin in the North–Western Parts of the Zanskar Mountains, Ladakh, Jammu and Kashmir. In: Sinha A. K. (Ed.) – Contemporary Geoscientific Researches in Himalaya, v. 1, pp. 177–188, 4 text–figs., Dehra Dun, – dealing with the stratigraphy of the area comprised between the Ringdom Gompa and Kangi–Mulbeck. The authors identified the following stratigraphic units: 1) the Lilang Group, extended surprisingly higher to include units here attributed to the Giumal Sandstone; 2) the Kanji Group, dated as Eocene, including three formations, transgressive over the Lilang Group. The authors, however, did not recognize the fossiliferous layers here described.

The stratigraphic units, described in Ganesan et al.'s paper are mainly from the northern side of the Zanskar Range and do not apply to the Ringdom Gompa–Kangi La area.

Acknowledgements.

Prof. R. Radoicic (Beograd) discussed with E. Fois the Algae identifications. Dr. S. H. Frost (Houston) gave very useful suggestions for the coral taxonomy.

REFERENCES

Adams C. G. (1967) - Tertiary Foraminifera in the Tethyan, American, and Indo–Pacific Provinces. In: Adams C. G. & Ager D. V. (Eds.)–Aspects of Tethyan Biogeography. *Sistem. Ass. Publ.*, 7, pp. 195–217, London.

Andrews–Speed C. P. & Brookfield M. E. (1982) - Middle Paleozoic to Cenozoic Geology and Tectonic Evolution of the Northwestern Himalaya. *Tectonophysics*, v. 82, pp. 253–275, 7 figs., Amsterdam.

Bassoullet J. P., Bernier P., Conrad M. A., Deloffre R. & Jaffrezo M. (1978) - Les Algues Daycladales du Jurassique et du Crétacé. *Géobios*, Mem. Sp. 2, pp. 1–330, 40 pls., Lyon.

Bassoullet J. P., Colchen M., Juteau Th., Marcoux J., Mascle G. & Reibel G. (1982) - Geological studies in the Indus Suture Zone of Ladakh (Himalayas). In: Gupta V. J. (Ed.) - Stratigraphy and Structure of Kashmir and Ladakh Himalaya (in press).

Baud A., Arn R., Bugnon P., Crisinel A., Dolivo E., Escher A., Hammerschlag J.C., Marthaler M., Masson H., Steck A. & Tieche J. C. (1982) - Le contact Gondwana–péri–Gondwana dans le Zanskar oriental (Ladakh, Himalaya). *Bull. Soc. Géol. France*, s. 7, v. 24, pp. 341–361, 10 figs., Paris.

Baud A., Gaetani M., Fois E., Garzanti E., Nicora A. & Tintori A. (1982) - Les séries tibetaines de l'Himalaya sont–elles allochtones: nouvelles observations dans le Zanskar oriental (Inde du N). *Soc. Géol. France, IX RAST*, p. 33, Paris.

Bismuth A., Bonnefous J. & Dufauré P. (1967) - Mesozoic microfacies of Tunisia. In: Guidebook to the geology and history of Tunisia. *Petroleum Expl. Soc. Libya 9th Annual Field Confer.*, pp. 159–214, 27 pls., Amsterdam.

Bozorgnia F. (1964) - Microfacies and microorganisms of Paleozoic through Tertiary sediments of some parts of Iran. 22 pp., 158 pls., 1 map, Ed. NIOC, Teheran.

Brookfield M. E. & Andrews–Speed C. P. (1982) - Sedimentology of the Indus Flysch and molasse, and its bearing on the evolution of the collision zone between India and Asia. *Sedim. Geology* (in press).

Carter N. L., Christie J. M. & Griggs D. T. (1964) - Experimental deformation and recrystallization of quartz. *Journ. Geology*, v. 72, pp. 687–733, 10 pls., 14 figs., Chicago.

Caus E., Hottinger L. & Tambareau Y. (1980) - Plissements du «septal flap» et système de canaux chez *Daviesina*, Foraminifères paléocènes. *Ecl. Geol. Helv.*, v. 73, n. 3, pp.1045 –1069, 4 pls., 7 figs., Bâle.

Collins J.S.H. & Morris S. F. (1975) - A new crab, *Costacopluma concava*, from the Upper Cretaceous of Nigeria. *Palaeontology*, v. 18, pp. 823–829, 1 pl., 1 fig., London.

Conolly J. R. (1965) - The occurrence of polycrystallinity and undulatory extinction in quartz in sandstones. *Journ. Sed. Petr.*, v. 35, pp. 116–135, 13 figs., Tulsa.

Davies L.M. (1927) - The Ranikot Beds at Thal (North–West Frontier Prov. of India). *Quart. Journ. Geol. Soc.*, v. 83, n. 2, pp. 260–290, 5 pls., 7 figs., London.

Dickinson W. R. (1970) - Interpreting detrital modes of greywacke and arkose. *Journ. Sed. Petr.*, v. 40, pp. 695–707, 2 figs., Tulsa.

Dilley F. C. (1973) - Cretaceous Larger Foraminifera. In: Hallam A. (Ed.) – Atlas of Palaeobiogeography, pp. 403–419, 12 figs., Elsevier, Amsterdam.

Elliott G. F. (1968) - Permian to Paleocene Calcareous Algae (Dasycladaceae) of the Middle East. *Bull. Brit. Mus. (Nat. Hist.) Geology*, Suppl. 4, 111 pp., 24 pls., 15 figs., London.

Embry A. F. & Klovan J. E. (1971) - A Late Devonian reef tract on north–eastern Banks Island, Northwest Territories. *Can. Petrol. Geol. Bull.*, v. 19, pp. 730–781, Calgary.

Folk R. L. (1980) - Petrology of Sedimentary Rocks. 185 pp., Hemphill's Publ., Austin.

Frank W., Gansser A. & Trommsdorff V. (1977) - Geological observations in the Ladak Area (Himalaya). A preliminary Report. *Schweiz. Min. Petr. Mitt.*, v. 57, pp. 89–114, Zürich.

Fuchs G. (1977) - Traverse of Zanskar from the Indus to the Valley of Kashmir - a preliminary note. *Jahrb. Geol. Bundesanst.*, v. 120, pp. 219–229, 1 pl., 1 fig., Wien.

Fuchs G. (1979) - On the Geology of Western Ladakh. *Jahrb. Geol. Bundesanst.*, v. 122, pp. 513–540, 12 figs., Wien.

Fuchs G. (1981) - Outline of the Geology of the Himalaya. *Mitt. Oest. Geol. Ges.*, v. 74–75, pp. 101–127, 1 map, Wien.

Fuchs G. (1982 a) - The Geology of Western Zanskar. *Jahrb. Geol. Bundesanst.*, v. 125 (in press).

Fuchs G. (1982 b) - Explanations of the Geologic – Tectonic Map of the Himalaya. 50 pp., 13 figs., 1 map., Ed. Geol. Bundesanst., Wien.

Gaetani M., Nicora A. & Premoli Silva I. (1980) - Uppermost Cretaceous and Paleocene in the Zanskar Range (Ladakh–Himalaya). *Riv. It. Paleont. Strat.*, v. 86, n. 1, pp. 127–166, 9 pls., 6 figs., Milano.

Gansser A. (1964) - Geology of the Himalayas. Vol. of 289 pp., 95 pls., 149 figs., 2 maps, London.

Glaessner M. F. (1969) - Arthropoda 4. Decapoda. In: Moore R. C. (Ed.) – Treatise on Invertebrate Paleontology, pp. 399–533, 626–628, 124 figs., *Geol. Soc. America & Un. Kansas Press*, Lawrence.

Gorsel J. T. van (1978) - Late Cretaceous Orbitoidal Foraminifera. In: Hedley R. H. & Adams C. G. (Eds.) – Foraminifera, v. 3, pp. 1–120, 30 fig., Academic Press, London.

Gusic I. (1967) - New *Dasycladaceae* from the Maastrichtian of Bespelj near Jaice (Western Bosnia). *Geol. Viesnik*, v. 20, pp. 117–126, 6 pls., Zagreb.

Hayden H. H. (1907) - The geology of the provinces Tsang and U in Tibet. *Mem. Geol. Surv. India*, v. 36, n. 2, pp. 122–201, 14 pls., Calcutta.

Henson F. R. S. (1948) - Larger imperforate Foraminifera of South–Western Asia. 127 pp., 16 pls., 16 figs., Ed. Brit. Mus. (Nat. Hist.), London.

Ho Yen, Zhang Ping–Kao, Hu Lang–Ying, Sheng Jing–Chang (1976) - Mesozoic and Cenozoic Foraminifera from the Mount Jolmo Lungma Region. *Report Sc. Exp. Mount Jolmo Lungma Region (1966–1968)*, Palaeontology, v. 2, pp. 1–125, 36 pls., 1 fig., Sc. Presse, Peking (In Chinese).

Honegger K., Dietrich V., Frank W., Gansser A., Thöni M. & Trommsdorff V. (1982) - Magmatism and metamorphism in the Ladakh Himalayas. *Earth Plan. Sc. Letters*, v. 60, pp. 253–292, Amsterdam.

Hottinger L. (1973) - Selected Paleogene Larger Foraminifera. In: Hallam A. (Ed.) – Atlas of Palaeobiogeography, pp. 443–452, 6 figs., Elsevier, Amsterdam.

Kelemen P. B. & Sonnenfeldt M. D. (1981) - Observations on Stratigraphy, Structure, Petrology and Tectonics from traverses in Central Ladakh and Zanskar, 61 pp., 6 figs. (Manuscript).

Kureshy A. A. (1977) - The Cretaceous larger foraminiferal biostratigraphy of Pakistan. *J. Geol. Soc. India*, v. 18, pp. 662–667, Bombay.

Kureshy A. A. (1978) - Tertiary larger foraminiferal zones of Pakistan. *Rev. Esp. Micropaleont.*, v. 10, n. 3, pp. 467–483, 8 figs., Madrid.

Latif M. A. (1976) - Stratigraphy and Micropaleontology of the Galis Group of Hazara, Pakistan. *Geol. Bull. Panjab Univ.*, n. 13, 65 pp., 16 pls., 4 figs., Lahore.

Massieux M. (1966) - Les Algues du Nummulitique Egyptien et des terrains Crétaces–Eocènes de quelques régions mésogéennes. *Rev. Micropaléont.*, v. 9, n. 2–3, pp. 111–146, 8 pls., 8 figs., Paris.

Metzeltin S. & Nicora A. (1977) - A new Eocene outcrop from Zanskar Range, Himalaya. *Riv. It. Paleont. Strat.*, v. 83, n. 4, pp. 803–824, 4 pls., 6 figs., Milano.

Morellet M. L. in Douvillé H. (1916) - Le Crétacé et l'Eocène du Tibet Central. *Palaeontologia Indica.* N. S., v. 5, mem. 3, pp. 1–52, 16 pls., 21 figs., Calcutta.

Mu En–zhi, Yin Ji–xiang, Wen Shi–xuan, Wang Yi–gang, Zhang Bing–gao (1973) - Stratigraphy of the Mount Jolmo Lungma Region in Southern Tibet, China. *Scientia Geol. Sinica*, v. 1, pp. 3–36, Beijing.

Nagappa Y. (1959) - Foraminiferal biostratigraphy of the Cretaceous–Eocene succession in the India–Pakistan–Burma region. *Micropaleont.*, v. 5, n. 2, pp. 145–192, 11 pls., 11 figs., New York.

Premoli Silva I. (1970) - The Cretaceous and Paleocene microfaunas from North–East Afghanistan. In: Desio A. (Ed.) – Fossils of North–east Afghanistan. *Italian Exp. to the Karakorum and Hindu–Kush, Scient. Reports*, v. 4, n. 2, pp. 119–160, 8 pls., 1 fig., Ed. E. J. Brill, Leiden.

Sampó M. (1969) - Microfacies and microfossils of the Zagros Area, Southwestern Iran. (From Pre–Permian to Miocene). 87 pp., 105 pls., 6 figs., Ed. E. J. Brill, Leiden.

Samuel O., Borza K. & Kohler E. (1972) - Miciofauna and Lithostratigraphy of the Paleogene and adjacent Cretaceous of the Middle Vah Valley (West Carpathian). 246 pp., 180 pls., 22 figs., Ed. Geol. Ustav Dionyza Stura, Bratislava.

Sander N. J. (1962) - Aperçu paléontologique et stratigraphique du Paléogène en Arabie Séaudite Orientale. *Rev. Micropaléont.*, v. 5, n. 1, pp. 3–40, 5 pls., 8 figs., Paris.

Skolnick H. (1965) - The quartzite problem. *Journ. Sed. Petr.*, v. 35, pp. 12–21, 9 figs., Tulsa.

Sliter W. V. (1977) - Cretaceous benthic Foraminifers from the western South Atlantic Leg 39, Deep Sea Drilling Project. In: Supko P.R., Perch–Nielsen K. et al. - *Init. Repts. D.S.D.P.*, v. 39, pp. 657–697, 13 pls., 13 figs., Washington (U. S. Govt. Printing Office).

Smout A. H. (1954) - Lower Tertiary Foraminifera of the Qatar Peninsula. 97 pp., 15 pls., 44 figs., Ed. Brit. Mus. (Nat. Hist.), London.

Srikantia S. V., Ganesan T. M., Rao P. N., Sinha, P. K. & Tirkey B. (1980) - Geology of Zanskar area, Ladakh Himalaya. *Himalayan Geology*, v. 8, pt. 2 (1978), pp. 1009–1033, 2 figs., Dehra Dun.

Srikantia S. V. & Razdan M. (1979) - The ophiolite–sedimentary belt of the Indus tectonic zone of the Ladakh Himalaya. Its stratigraphic and tectonic significance. *Proc. Int. Oph. Symp.*, pp. 430–443, 9 figs., Cyprus.

Stenzel H. B. (1971) - Mollusca 6. Bivalvia. Oysters. In: Moore R. C. (Ed.) – Treatise on Invertebrate Paleontology, pp. 953–1224, 153 figs., *Geol. Soc. America & Un. Kansas Press*, Lawrence.

Tibetan Scientific Expedition Team Academia Sinica (1975) - A report of a scientific expedition in the Mount Jolmo Lungma region (1966–1968), fasc. 2, pp. 425–457, 12 pls., Peking.

Trommsdorff V., Dietrich V. & Honegger K. (1982) - The Indus Suture Zone: Paleotectonic and Igneous evolution in the Ladakh Himalaya. In: Hsu K. J. (Ed.) – Mountain Building, Academic Press, London (in press).

Vail P. R., Mitchum R. M. jr. & Thompson S. III (1977) - Global Cycles of relative changes in sea level. *Amer. Assoc. Petr. Geol.*, Mem. 26, pp. 83–97, 2 figs., Tulsa.

Vredenburg W. E. (1916) - *Flemingostrea*, an eastern group of Upper Cretaceous and Eocene *Ostreidae*: with descriptions of two new species. *Geol. Surv. India, Records*, v. 47, pp. 196–203, 4 pls., Calcutta.

Young S. W. (1976) - Petrographic texture of detrital polycrystalline quartz as an aid to interpreting crystalline source rocks. *Journ. Sed. Petr.*, v. 46, pp. 595–603, 6 figs., Tulsa.

PLATE 7

Fig. 1 – Longitudinal/oblique section of *Cymopolia* aff. *eochoristosporica* Elliott. Note the strongly elongated distal portion of primary branches. Thin section H 7c; x 12.

Fig. 2 – Longitudinal/oblique section of *Cymopolia* aff. *eochoristosporica* Elliott. Thin section H 16 a; x 8.3.

Fig. 3 – a) Longitudinal/oblique section of *Cymopolia tibetica* Morellet showing the swollen distal portion of primary branches; b) oblique sections of *C.* aff. *eochoristosporica* Elliott. Thin section H 7b 3; x 11.2.

Fig. 4 – a) Oblique section of *C. tibetica* Morellet; b) tangential section of *C.* aff. *eochoristosporica* Elliott. Thin section H 7b 2; x 11.2.

Fig. 5 – Transverse sections of *C.* aff. *eochoristosporica* Elliott. Thin section H 7b 1; x 11.2.

Fig. 6 – Longitudinal/oblique section of *C.* aff. *eochoristosporica* Elliott. Thin section H 7A; x 10.

Fig. 7 – Transverse/oblique section of *C.* aff. *eochoristosporica* Elliott in which secondary branches are completely abraded. Thin section H 16b; x 12.8.

Fig. 8 – Longitudinal/oblique section of *C. tibetica* Morellet. Note the swollen portion of primary branches and the sphaerical sporangium (arrow). Thin section H 16D; x 12.8.

Fig. 9 – Oblique section of a solitary coral, *Epistreptophyllum* sp. Thin section H 7b 1; x 10.

All samples from the Kangi Chu section.

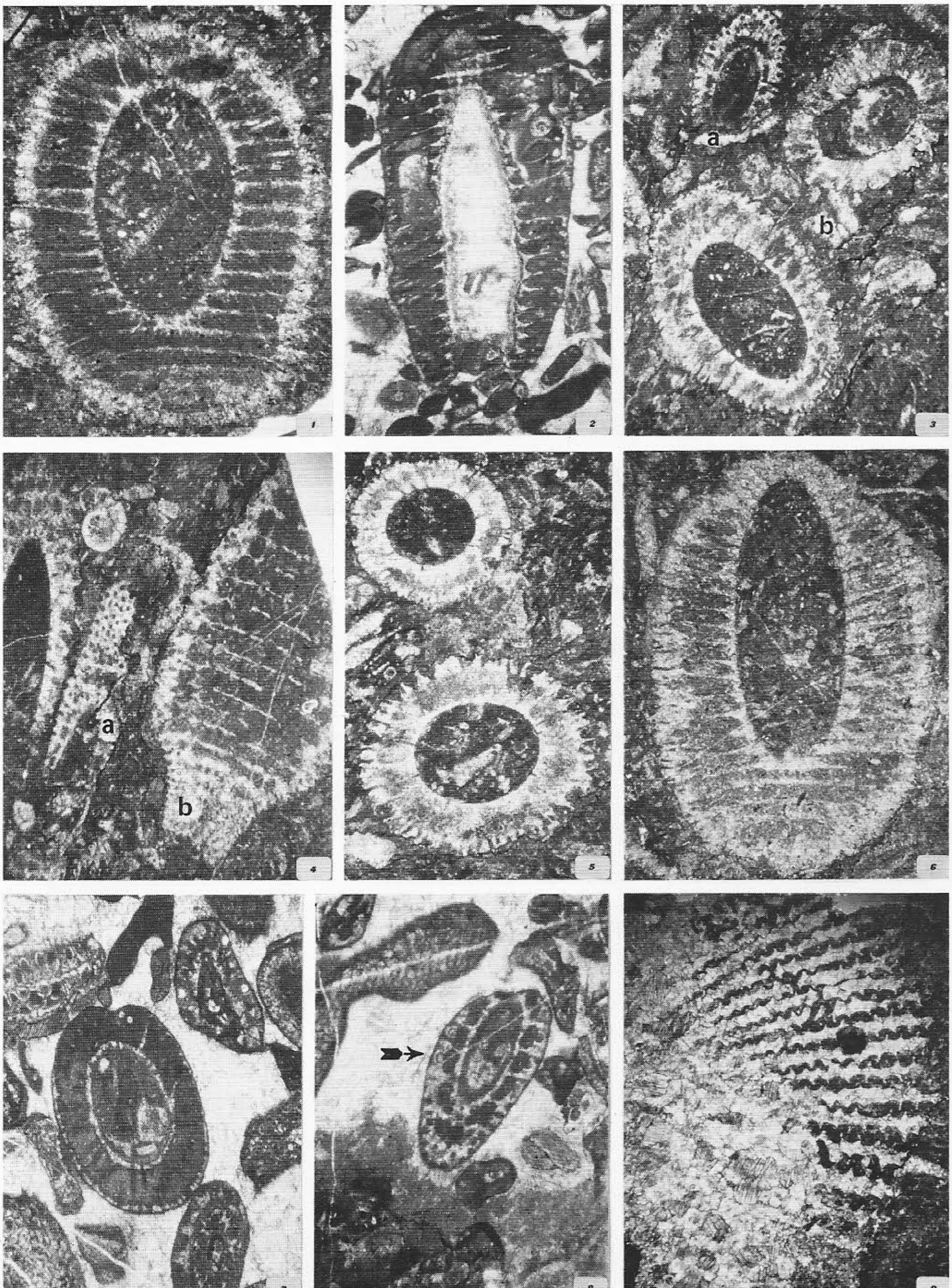

a
b
a
b

PLATE 8

Fig. 1 – Fragment of *Cymopolia tibetica* Morellet. Note the very short primary branch with the swollen distal portion and the sphaerical sporangium in between the elongated secondary branches. Thin section H 16A; x 28.

Fig. 2 – Transverse section of *Cymopolia tibetica* Morellet. Thin section H 8A; x 12.8.

Fig. 3 – Longitudinal/oblique section of *C. tibetica* Morellet. Thin section H 16A; x 12.8.

Fig. 4 – Fragment of a longitudinal section of *C. tibetica* Morellet in which is very clear the shape of the swollen distal portion of primary branches and of the sporangium. Thin section H 8B; x 17.6.

Fig. 5 – Transverse/oblique section of *C. tibetica* Morellet. Thin section H 16B; x 16.

Fig. 6 – Oblique sections of *C. tibetica* Morellet. Thin section H 8A; x 11.2.

Fig. 7 – Longitudinal/oblique section of *C. tibetica* Morellet well displaying the sphaerical sporangium and the swollen portion of the primary branches. Thin section H 8B; x 10.

Fig. 8 – Tangential section of *C. tibetica* Morellet. Thin section H 16B; x 10.

Fig. 9 – Longitudinal/oblique section of *Cymopolia heraki* Gusic. Note the sphaerical sporangium (arrow) and the secondary branches with a funnel shaped ending. Thin section HZ 122; x 9.6. Spanboth Chu section.

All samples from the Kangi Chu section, except HZ 122 from Spanboth Chu section.

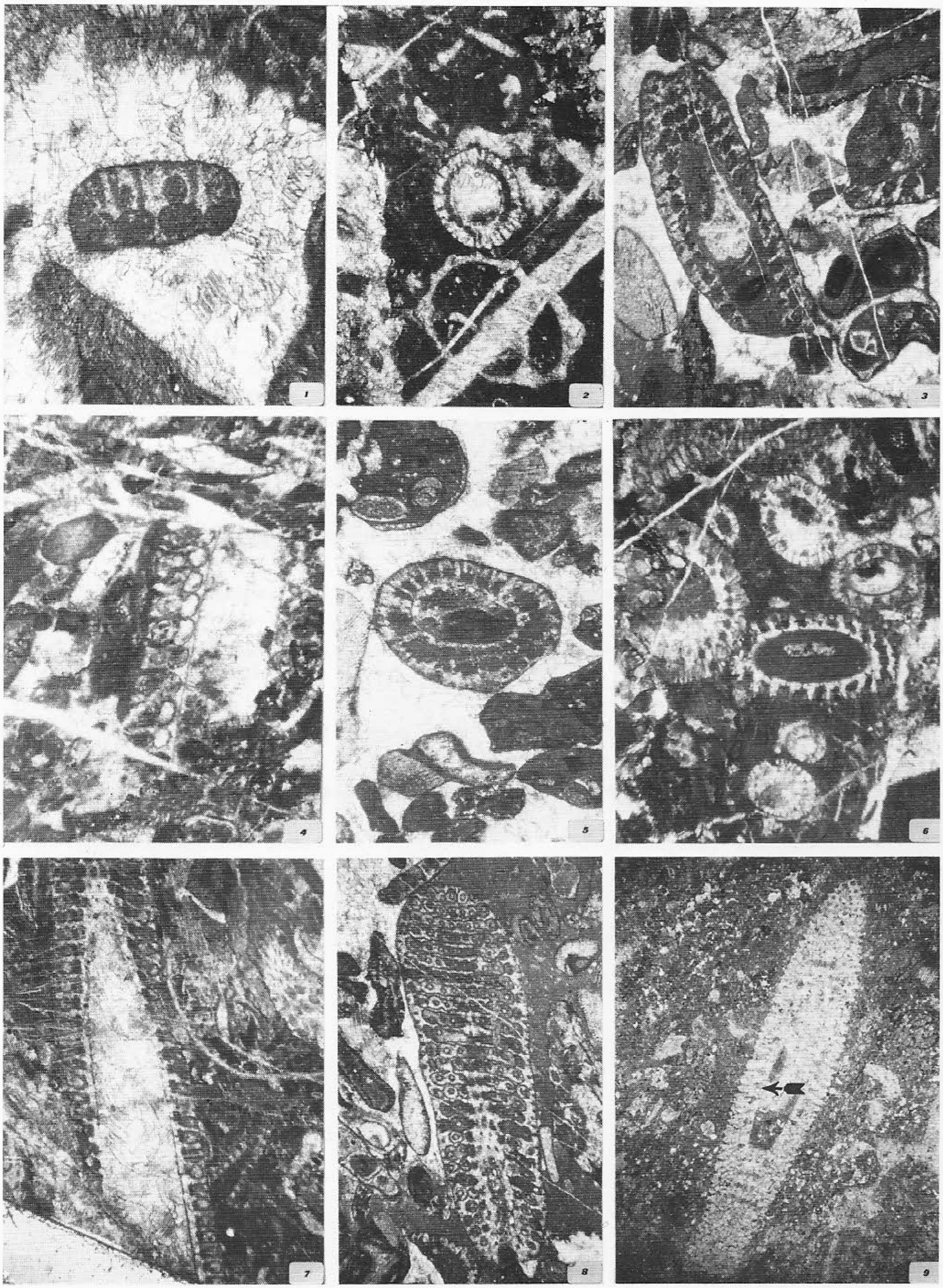


PLATE 9

Fig. 1 – Longitudinal/oblique section of *Cymopolia heraki* Gusic. Thin section HZ 138; x 10.8.

Fig. 2 – Longitudinal/oblique section of *Cymopolia* aff. *eochoristosporica* Elliott. Thin section HZ 140; x 8.4.

Fig. 3 – Tangential/oblique section of *Cymopolia* cf. *eochoristosporica* Elliott. Thin section HZ 120; x 13.5.

Fig. 4 – Transverse section of *Cymopolia* cf. *tibetica* Morellet. Thin section HZ 141; x 20.

Fig. 5 – Transverse section of *Furcoporella* sp. Thin section HZ 155; x 12.

Fig. 6 – Longitudinal/tangential section of *Furcoporella* sp. Thin section HZ 157; x 12.

Fig. 7 – Longitudinal/tangential section of *C.* cf. *tibetica* Morellet. Thin section HZ 139; x 13.5.

Fig. 8 – Fragment of a tangential section of *Furcoporella* sp. Thin section HZ 157; x 27.5.

Fig. 9 – Longitudinal/tangential section of *Furcoporella* sp. Thin section HZ 155; x 27.5.

Fig. 10 – Axial and oblique sections of fragmented *Operculina* and *Ranikothalia*?. Thin section HZ 173; x 9.

All samples from the Spanboth Chu section.

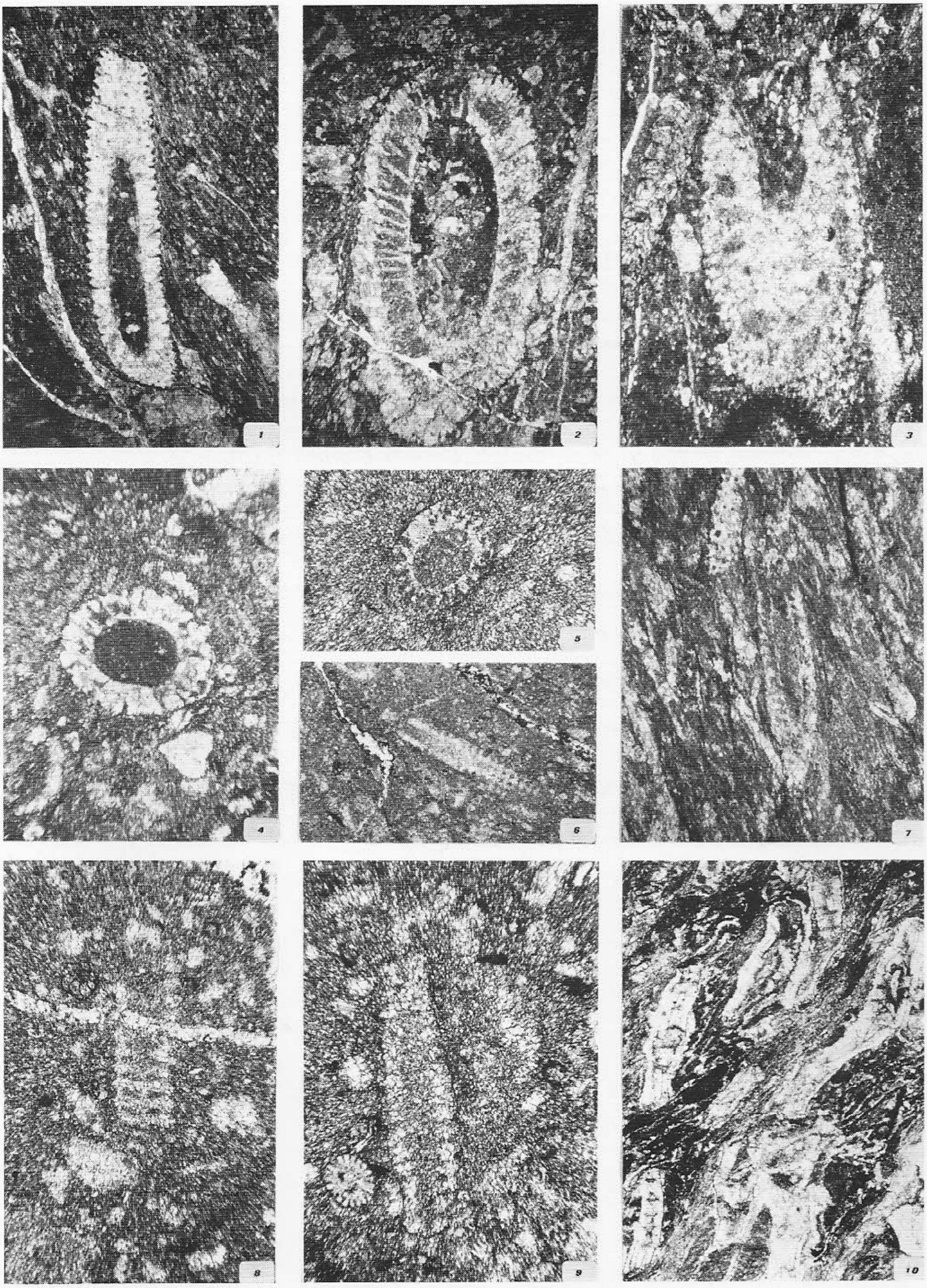


PLATE 10

Fig. 1 – *Lockhartia* cf. *haimei* (Davies). Oblique/axial section (a), and differently oriented sections of Rotaliids. Thin section HZ 162; x 14.

Fig. 2 – *Rotalia* sp. Axial section (a), and differently oriented sections of Rotaliids, possibly also *Lockhartia*. Thin section HZ 179; x 17.

Fig. 3 – *Lockhartia* sp. Axial section and oblique section. Thin section HZ 171; x 15.

Fig. 4 – a) Marginal section of *Daviesina* ?; b) *Daviesina danieli* Smout, axial section; c) fragment of *Lockhartia* sp. Thin section HZ 170; x 20.

Fig. 5 – a) *Ranikothalia* sp. Axial section; b) Rotaliid ? Thin section HZ 174; x 17.

Fig. 6 – *Rotalia* cf. *trochidiformis* Lamarck, nearly axial section and small Forams. Thin section HZ 156; x 20.

Fig. 7 – *Fissoelphidium* sp. Axial section. Thin section HZ 142; x 17.

Fig. 8 – *Daviesina danieli* Smout. Axial section. Thin section HZ 170; x 20.

Fig. 9 – a) Miliolids; b) nearly equatorial section of Rotaliid. Thin section HZ 179; x 17.

All samples from Spanboth Chu section.