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STRATIGRAPHY, MICROFACIES AND PALAEOENVIRONMENT OF THE LILANG GROUP (SCYTHIAN - DOGGER), SPITI VALLEY, HIMACHAL HIMALAYA, INDIA

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ABSTRACT

The Lilang Group is divisible into eight formations viz. the Mikin, Kaga, Chomule, Sanglung, Hangrang, Alaror, Nunuluka and Kioto, broadly coinciding with the well known biostratigraphic subdivisions of the 'Lilang System'. The Mikin, Kaga and Chomule Formations mainly comprise filamentous limestone enclosing molluscan remains. The Mikin and Kaga Formations represent sedimentation in open sea shelf and the Chomule Formation partly in the basin margin. The Sanglung Formation made up of packstone, floatstone and rudstone is a foreslope facies. The Hangrang Formation, embracing packstone, grainstone, floatstone and boundstone, forms knoll patch reefs on a platform. The Alaror Formation mainly ooidal, represents winnowed platform edge sand and lagoonal facies. The cross-bedded calcareous sandstone to arenaceous limestone of the Nunuluka Formation is an intertidal to estuarine facies representing a partial regression. The Kioto Formation consisting of coral pin reefs, ooidal grainstone, and shell hash packstone is a typical winnowed platform edge snd and shelf lagoon deposit with local todal channel conditions. The Kioto Formation marks transgressive phase, which deposited the Kioto Formation and its equivalents over the Lower Carboniferous in the Phiphuk area.

INTRODUCTION

The Lilang Group of the Spiti valley, Himachal Himalaya, is one of the best developed Triassic sequences in the world. Its outcrops are mainly exposed between 3500m and 5,500m above sea level. The

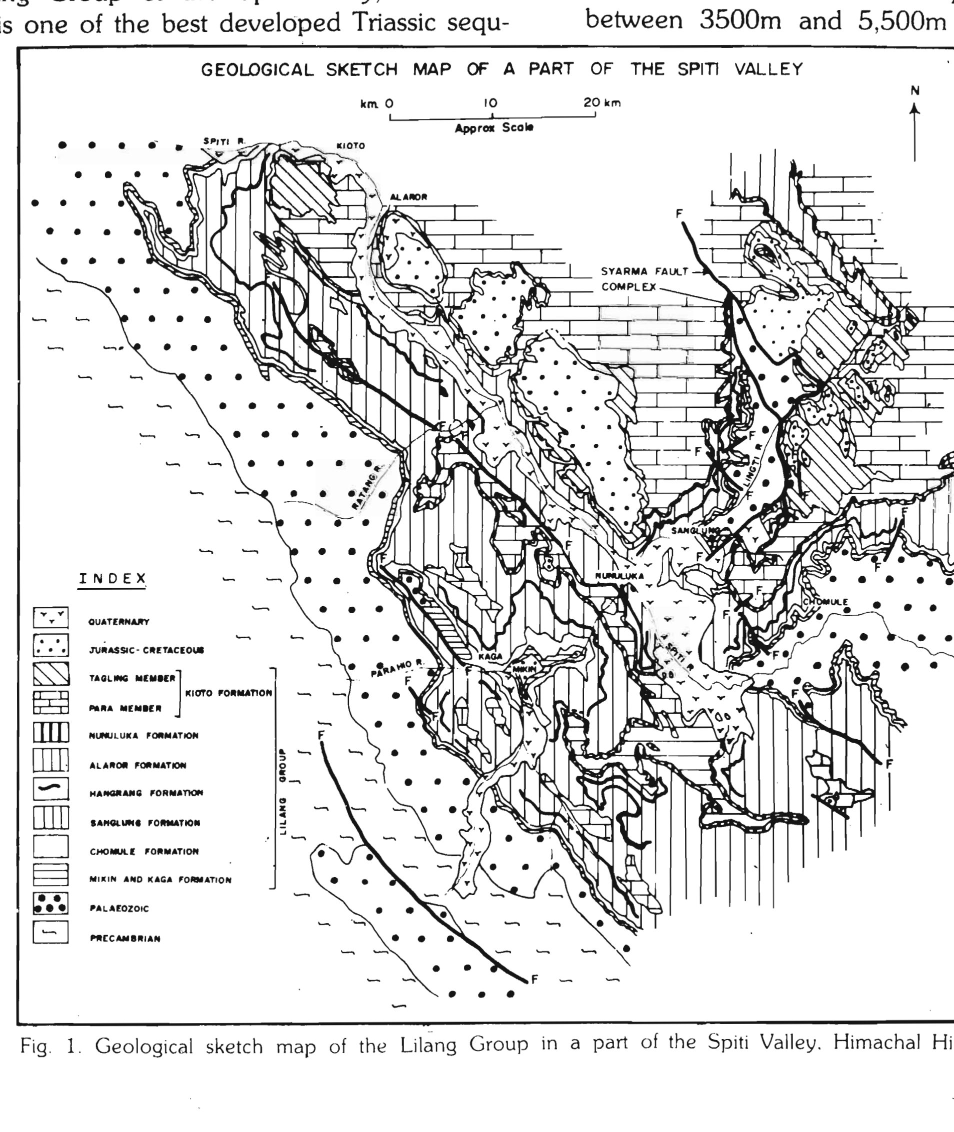

Fig. 1. Geological sketch map of the Lilang Group in a part of the Spiti Valley. Himachal Himalaya.

name Lilang was proposed by Stoliczka (1865) after the Lilang (pronounced as Laung) village. It was studied in detail by Hayden (1904, 1908) who defined the Lilang System as a sequence resting above and below the Kuling and the Kioto systems respectively. The biostratigraphy of the Lilang 'System' has been worked out in considerable details by Hayden (1904, 1908) and Diener (1912). The conodont fauna of the Lilang Group has been described by Goel (1977), Bhatt *et al*, (1908, 1981) and Gupta (1983). Srikantia (1981) made a beginning in lithostratigraphic classification of the Lilang Group. Fuchs (1982) prepared an excellent map of the Lilang Group of the Pin Valley area. Except for microfacies analysis of the 'Coral Beds' by Bhargava and Bassi (1985) no petrographic studies have been carried out on the carbonate rocks of the Lilang Group.

The present author undertook the mapping of the

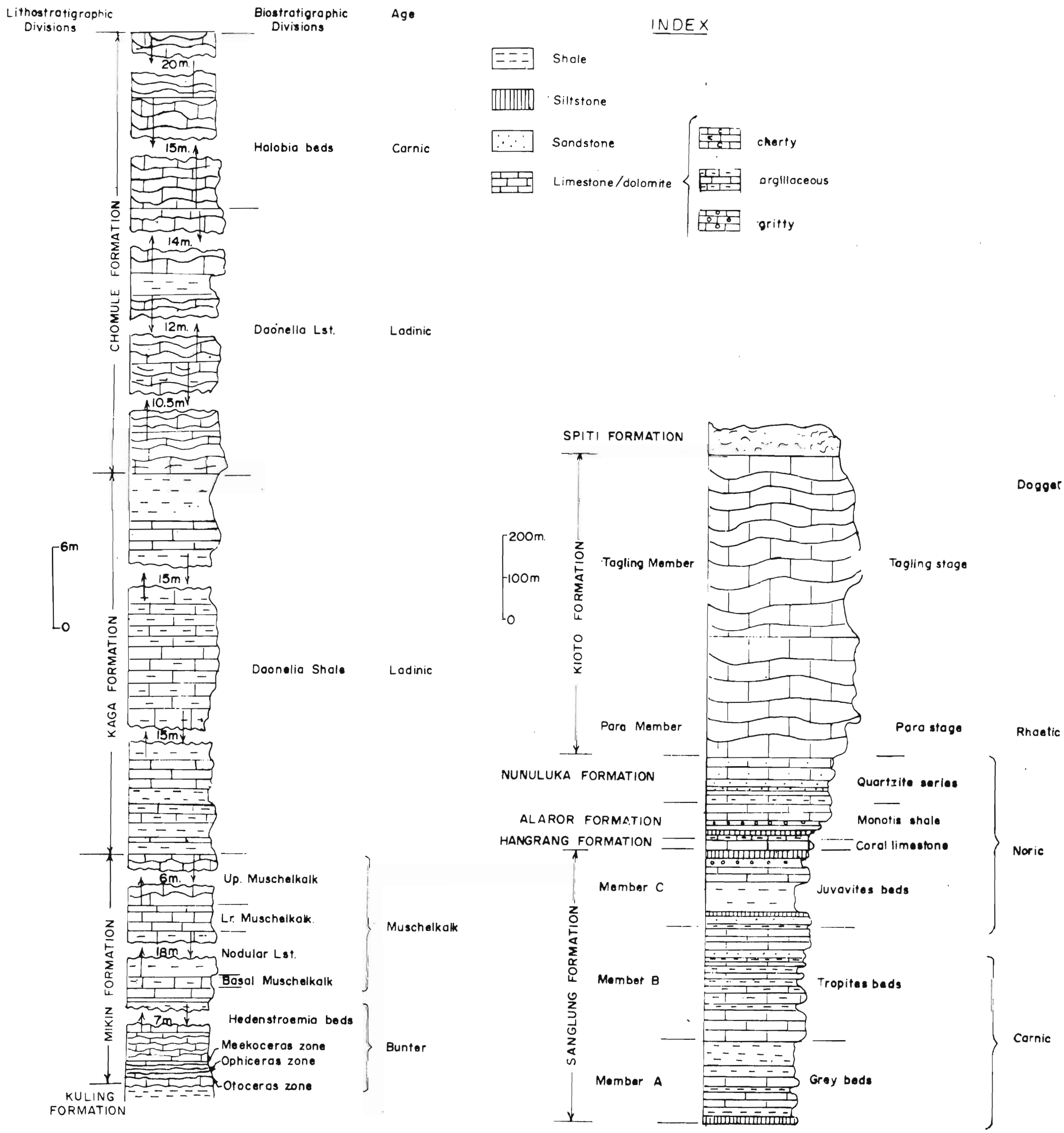

Fig. 2. Lithocolumn of the Lilang Group showing lithostratigraphic subdivisions against the biostratigraphic subdivisions.

Lilang Group on 1:50,000 scale during the summers of 1982-1984. Initially the Lilang Group subdivided into five formations (Bhargava and Bassi, 1985). As the mapping progressed it was found to be classifiable into eight formations which are traceable through out the Spiti Valley spanning over an ara of more than 5000sq. km. The present paper describes the stratigraphy, microfacies and palaeoenvironments of the Lilang Group. The microfacies studies were confined to the carbonate rocks mainly of the Lilang type section. The lithostratigraphic subdivisions proposed here broadly coincide with the biostratigraphic subdivisions (Fig. 2). Dunham's classification (1962) as modified by Embry and Klovan (1972) has been followed here while the palaeoenvronmental interpretations are after Wilson (1975) and Flugel (1982) with broad comparision with the actualistic models.

STRATIGRAPHY AND MICROFACIES

The Lilang Group, except in the upper Lingti valley, rests conformably over the shelf mud Kuling Formation (Permian) which is divisible into lower (a) Calcareous Sandstone and upper (b) Black Shale. In the upper lingti valley, east of Syarma Fault the Rhaetic Kioto Formation rests over rocks supposed to be Lower Carboniferous, thus signifying a large hiatus. Various subdivisions of the Lilang Group are described below.

MIKIN FORMATION: It is named after the Mikin village in the Parahio valley around which excellent section of this formation is developed. It is equally well developed near Guling, opposite Lilang village along the right bank of the Lingti river and north of Tabo and Po villages. This formation corresponds to the combined biostratigraphic subdivisions of the *Otoceras*, *Ophiceras*, *Meekcceras* zones, *Hedenstroemia* beds, Basal Muschelkalk, Nodular limestone and Lower and Upper Muschelkalk.

About 5-10 cm above its contact with the shale of the Kuling Formation, the Mikin Formation in all the sections has a 1-10 cm thick ferruginous band having sharp contacts with the underlying and overlying beds. The Mikin Formation comprises thick to medium, evenly bedded dark grey dolomite which is cherty at places. Dark grey to ash grey minor cherty shales occur within the sequence. A net work of fine ferruginous veins occurs through out the sequence and constitutes the most diagnostic feature of the formation.

Nodular and wavy beddings and fairly large subaqueous slumps are conspicuous in the Mikin Formation, Besides conodonts, *Ophiceras* is the most abundant fossil in this sequence. Forming precipitous slopes, it is consistently developed through out the valley.

Microfacies : (a) Extensively stylomottled filamentous wackestone/packstone (P1/1-3) is most common. It shows variations to (i) Thin shelled cephalopod (P1/1), (ii) shelled gastropod, (iii) Thin shelled normally to overpacked lamellibranch nodular wackestone/packstone with or without ?radiolaria and calcisphere (P1 1/2, 10; P1 2/3) and sporadic graded beding (P1 1/5), (iv) Juvenile normal to overpacked cephalopod micropeloidal límestone. In these sporadic echinoid and ostracode remains are also present. The bioturbated part shows circular arrangement of thin shelled fragments with cloudy rim and central part filled with blocky sparite (P1 1/6). Some of the bioclasts and lithoclasts are iron coated. This microfacies is rare, (b) Mudstone forms a subordinate facies. The cement is inconspicuous, mostly micritic.

KAGA FORMATION: Lithologically as well as fossil-content wise, it is best developed along the Kaga brook. A good section is also exposed along the right bank of the Lingti river opposite Lilang Village. It corresponds to the *Daonella* Shale biostratigraphic subdivision. *Daonella* is by far the most dominat fossil of this formation.

The Kaga Formations consists of light to dark grey green calcareous shale weathering to earthy yellow. Lenticular subordinate limestone/dolomite interbeds occur sporadically in the sequence. Cephalopods, occurring as 'dropstone' are crowded along limestone-shale interface in certain basal beds. Such features are observed in thin sections also.

In between the Mikin and Chokule Formations it forms earthy coloured gentle slopes.

Microfacies : (a) Filamentous limestone containing fragments of juvenile as well as adult *Daonella* (Pl 1/8), (b) Layered medium walled lamellibranch packstone (Pl 1/4), (c) Cephalopod dropstone in layered thin shelled packstone (Pl 1/9), (d) Thin shelled lamellibranch packstone with disconformity (Pl 1/7), (e) Dark grey mudstone. All the bioclasts are mainly thin shelled. Some of the clasts have dark rims, stylolites are low-peaked. The burrow fillings are (i) dark micritic with fine organic debris, (ii) Fe-rich micrite and rarely, (iii) blocky sparite. The cement otherwise is inconspicous and micritic.

CHOMULE FORMATION: Good exposures of this formation are found all over the Spiti valley with the best development at Chomule and along the left bank of the Lingti river opposite Lilang village. It equals the biostratigraphic subdivisions of the *Daonella* limestone and the *Halobia* beds.

The Chomule Formation is made up of evenly bedded light grey dolomite in the basal part and dark grey cherty dolomite in the upper, with subordinate calcareous shale and marl beds. All these lithounits weather to light ash grey colour. The uniform bedding thickness of the dolomite along with nodular and wavy beddings is one of the most prominent characters of this formations which can be viewed from distance. *Daonella* is common in the basal part while in the upper *Halobia* is sporadic to common. Through out the valley it forms escarpments.

Microfacies : (a) Filamentous lamellibranch wackestone/packstone containing shells/shell fragments of *Daonella* and *Halobia*, (b) Thin shelled gastropod limestone, (c) Calcitised radiollarian (*? Dorydictyum*) mudstone/wackstone (Pl 2/1, 2) (d) Mudstone with sparite and micrite clasts. Bioturbation is rare, these are in the form of circular arrangement of grains. Stylotites vary from low peaked to brecciated type. Cement is inconspicuous and micritic.

SANGLUNG FORMATION: It is divisible into three units which could be raised to formation level. However, the middle unit pinches out in several inaccessible sections where it has not been possible to ascertain whether the pinching is structural or sedimentologic. Due to this lacuna these subdivisions have been accorded member's status and mapped together.

Member: It shows excellent development at Sanglung in the Pin valley around Guling and left bank of the Lingti, opposite Lilang village. It corresponds to the Grey Beds of Dieney 1912).

The A Member comprises grey shale which weathers to ash grey colour with dolomite and earthy dolomite. The shale ratio in different sections varies from 60% to 80%. Due to highly folded nature of the sequence the dolomite beds pinch possibly due to structural stretching. *Spiriferena shalshalensis* and bivalve fragments are common in this member. It forms somewhat gentler to steep slopes.

Microfacies : These from bottom to top are represented by (a) Bioclastic/lithoclastic wackestone/packstone, (b) Thin shelled stylobrecciated packstone (Pl 2/6), (c) Calcareous sandstone enclosing coral and tabulzoan fragments (Pl 2/7), (e) Mudstone, (f) Bioclastic packstone with dark brown matrix (20% to 30%) and lighter coloured bioclasts of bryozoa, echinoid plates and spines, crinoid ossicles, sponge, foraminifera, oyster shell and ? fish tooth (Pl 2/8). The cement varies from micritic to syntaxial.

Member B : It is also well exposed at Sanglung and right bank of the Lingti river opposite Lilang village. It corresponds to the *Tropites* beds.

This member comprises bedded grey dolomite with subordinate shale, siltstone and calcareous sandstone. The dolomite is cherty in upper part. *Tropites* is sporadically present in this member. It mostly forms precipitous slopes.

Microfacies: (a) Lithoclastic/bioclastic packstone/wackestone/ grainstone/mudstone (Pl 2/4). The cement around bioclasts is syntaxial, followed by micritic.

Member C : It is excellently exposed along Atargoo-Guling road and corresponds to the *Juvavites* beds.

It consists of shale, ferruginous grey sandstone and breccia with angular to sub angular boulder/cobbles size fragments to limestone and sandstone (e.g. Hal Section). The shale and siltstone weather to brownish and green colours. Sandstone shows well preserved low angled cross-bedding. Interference ripple marks are present in sandstone and dolomite beds. Ichnofossils *Skolithos* in sandstone and *Rhizocorallium* (parallel to subparallel to bedding) in shale are abundantly present. It forms gentle to steep slopes.

Microfacies : (a) Hydroza bindstone (local facies) Pl 2/10), Lamellibranch grainstone/packstone (Pl 2/11) (abundant facies).

HANGRANG FORMATION: The most spectacular development of this formation is observed in the Hangrang Pass area. Good sections are exposed at Chidang, Pin-Spiti confluence and Lilang. It is equivalent to the Coral limestone.

The Hangrang Formation is constituted of light to medium grey massive dolomite. It represents a reefoid facies (Bhargava and Bassi, 1985). Though the extent of reefoid structure varies from tens of square meters (e.g. Lilang) to a few km^2 (e.g. Hangrang), the formation retains reefoid characters in large parts of the Spiti valley with intervening non-reefal parts. In between the Sanglung and Alaror Formations this formation forms somewhat steeper topography and can be identified from a distance.

Microfacies : The microfacies of the Hangrang Formation from Kiomo, Latarse, Rangring and Pin-Spiti confluence in the Spiti valley have already been described (Bharvaga and Bassi, 1985). These include, (a) Bioclastic/lithoclastic/wackestone/floatstone (Pl 3/4), (b) Densely packed cortoidal packstone/grainstone (Pl 3/3), (c) Layered packstone/grainstone (Pl 3/1), (d) Poorly sorted oncoidal bioclastic floastone, (e) Normally packed oolitic wacketsone/packstone (Pl 3/5), (f) Bioclastic algal pelletoidal grainstone, (g) Bioclastic packstone/grainstone (Pl 3/2), (h) Framestones of various kinds, (i) Bindstones of various kinds, (j) Bafflestones of various kinds. The reef builders include sponge (*Colospongia Colospongia catenulata* Ott (Pl 3/1), *Peridonella, ? Paradeningeria, Dictyocoelia*) (b) Corals (*Montlivaltia, Stylophyllopsis, Thamnasteria rectilamellosa* Winkler, *Seriastraea multiphyllia* spp), (c) Hydrozoa (*?Cladocoropsis* (pl 3/4), *Spongiomorpha ramosa* Frech), (d) Tablzoa (*Zovecinipora*), (d) Microproblematica (*Pycnoporidium eomesozoicum* Flygel, *Microtubus,* (f) Solanoporid algae, (g) Forminifera (*Opthalmidium, Agathammina, ?Galeanella, Sigmolina*).

Reef dwellers are bivalve, gastropods, microcephalopods, brachiopods, ostracodes, echinoderms and serpulids.

ALAROR FORMATION: This name suggested by Srikantia (1981) is adopted here though the contents of this formation as defined now are quite different from those originally proposed. Besides in the vicinity of Alaror, it is very well developed along Attargoo-Guling road about 1 km upstream of Pin-Spiti confluence. It corresponds to the *Monotis* Shale.

It comprises dark grey to brownish shale with subordinate interbeds of limestone/dolomite and marl. In sections where the Hangrang Formation is not developed, it is difficult to distinguish between the C Member of the Sanglung Formation and the Alaror Formation. *Monotis* is fairly common in this formation. *Rhizocorallium* aligned subparallel to parallel to the bedding is commonly present in the grey shales. It forms gentle to steep topography.

Microfacies : (a) Sandy ooidal grainstone/packstone, (b) Layered mudstone with gastropod and lammellibranch in tempestite layer (Pl 3/6), (c) Shoal bivalve ooidal grainstone/packstone (Pl 3/9). The oolites are simple, compound and also complex enclosed in an ?alagal sheath (Pl 4/8, 10). The cement varies from blocky to equant.

NUNULUKA FORMATION: Its best exposures can be studies along the Atargoo-Guling road. As no locality name exists in this section, it has been named after Nunuluka which is the next best section. It corresponds to the Quartzite Series.

It consists of gritty grey to pale white calcareous sandstone in basal part, followed by coarse argillaceous sandstone. Within the sequence subordinate beds of grey shale and arenaceous dolomite occur. The sandstone is composed of moderately sorted, rounded to subrounded quartz set in a calcitic cement (5% - 15 %). The cement has marginally replaced quartz. The secondary cement is ferruginous.

Parallel bedding, low angled cross-bedding, current ripple marks showing parallel as well as wavy crest, interference ripple marks and sporadic load casts are present in the sandstone. If forms moderately steep topography.

Microfacies : (a) Sandy ooidal-algal packstone (local) (Pl 4/9). The cement is turbid blocky sparitic.

KIOTO FORMATION: With increase in the calcareous contents, the Nunuluka Formation passes into the Kioto Formation in complete sections. In other sections it rests over the Lower Carboniferous rocks (Phipuk section in the Upper Lingti valley) and over the Alaror Formation (Lidang section) due to sedimentologic breaks. The name Kioto was suggested by Hayden (1908). It is well exposed in the upper reaches of the Lingti valley, between the Parang and Lagudarsi Passes and at Phaldhar. It is divisible into two members. It is equivalent to the biostratigraphic subdivision '*Megalodon* Limestone' suggested by Diener (1912)

Para Member (= Para stage of Stoliczka, 1865): Its excellent exposures are present along the Ki-Kibber and Atargoo-Guling roads.

The Para Member comprises grey, pale creamish, sporadically cherty massive thick bedded dolomitic limestone. Large oncoidal and pisoidal structures are present along the Ki-Kibber road. Breccia and cut and fill structures are common in this member. Recrystallised whole and fragmented large megalodontid shells are abundantly present in most of the sections (Kiomo, Kioto and Ensa to name a few). It forms craggy terrain.

Microfacies : (a) Bioclastic wackestone/packstone (Pl 4/1, 5/8), (b) Foraminiferal peloidal grainstone/packstone (Pl 4/2, 3), (c) Peloidal aggregate/bioclastic lithoclastic floatstone/packstone (Pl 5/3).

Tagling Member: It inherits its name from the Tagling stage (Stoliczka, 1865) though the presently defined Tagling Member has a wider scope. It includes somewhat argillaceous dolomite. It is well exposed near the Tagling Pass, Sakti, Giumal and Kibber areas. It is made up of mildly ferruginous oolitic, pisolitic dolomite, cross-bedded bivalve-belemnite coquina, conglomerate and arenaceous limestone. Local small (30 cm^2) colonies of *Thecosmillia* (Pl 2/7) sporadically occur in Sakti area. The lithounits of this member weather to earthy yellow colour. The upper most part in contact with the Spiti Shale shows distorted oolites with glauconitic cement. As compared to the Para Member it forms softer topography.

Bioturbations and trace fossil *Planolites* are common in the Tagling Member. Megalodontids and lammellibranch shells are common and nerinids (*Plesioptyxis*, Bhargava, 1986) and belemnites are sporadic in this member.

Microfacies : (a) Peloidal aggregate lithoclastic graistone (Pl 4/4, 5), (b) Nerinid ooidal well packed grainstone/packstone (Pl 5/1, 3), (c) *Thecosmilia clathrata* (Emmrich) framestone (Pl 5/2), (d) Normally packed bioclastic grainstone (Pl 5/4), (e) Shell hash packstone with abundant micrite (Pl 5/5), (f) Oolitic grainstone with truncated ooids (Pl 3/7, 8), (g) Glauconitic distorted ooidal-forminiferal packstone (Pl 4/7, 5/8).

PALAEOENVIRONMENT

The palaeoenvironments interpreted in the Lilang Group, are listed below in stratigraphic order.

1. Open Sea Shelf to Basin Margin: (a) Mikin Formation: It is characterised predominantly by thin shelled-filamentous limestone/dolomite which is regarded to represent deeper water deposits of subtidal to bathyal facies (Wilson, 1975, Flugel, 1982). Presence of radiolaria, juvenile cephalopod and micropeloidal microfacies, nodular bedding, nodular conglomerate bound by laterally extensive microstylolites and subaqueous slumps (Wilson, 1975) support such an interpretation. A few coated grains represent material possibly flushed from the shallow depths. Several shells have intact valves and show settling effect pointing to the general absence of current. Irregular fabric observed in the filamentous limestone indicates presence of bottom currents, (b) Kaga Formation's subordinate limestone/dolomite are filamentous and form stylobrecciated fabric due to Fe material. This also indicates

subtidal of bathyal environments. Abundantly present *Daonella* — a pelagic bivalve (Wilson, 1975) tends to confirm this assumption. Numerous cephalopods of various sizes in the basal part of this formation. occur as dropstones. These are interpreted to have formed due to sudden influx of fine terrigenous material which caused suffocation of the animals and led to mass mortality (Bhargave *et al.*, 1985). Such features are also present on micro-scale. These organic dropstones indicate lack of current and deposition in a quiet shelf area. (c) The Chomule Formation largely comprising stylobrecciated mudstone, filamentous micrite enclosing thin shells of pelagic and deep water *Deonella* and *Halobia* (Wilson, 1975) and calcitised radiolaria (?) (*Dorydictyum*) possibly represent somewhat deeper facies at least in part of the sequence.

2. Upper Basin to Mainly Foreslope: The Sanglung Formation in the basal part shows thin shelled nodular micricite facies coexisting with sandy floatstone microfacies thereby indicating transistional location between the basin margin and foreslope. The middle and upper parts of the Sanglung Formation mostly have packstone, floatstone and rudstone facies pointing to a typical foreslope location. However, the basin was of low energy type located/below or near to wave base as is revealed by prolific development of *Rhizocorallium*. Fluctuations to littoral to circa-littoral conditions are interpreted in the upper part due to the presence of trace fossil *Skolithos*.

3. Buildups: Though no reef is found in the Sanglung Formation, reef breccia is quite common showing the beginning of organic buildup which, however, could

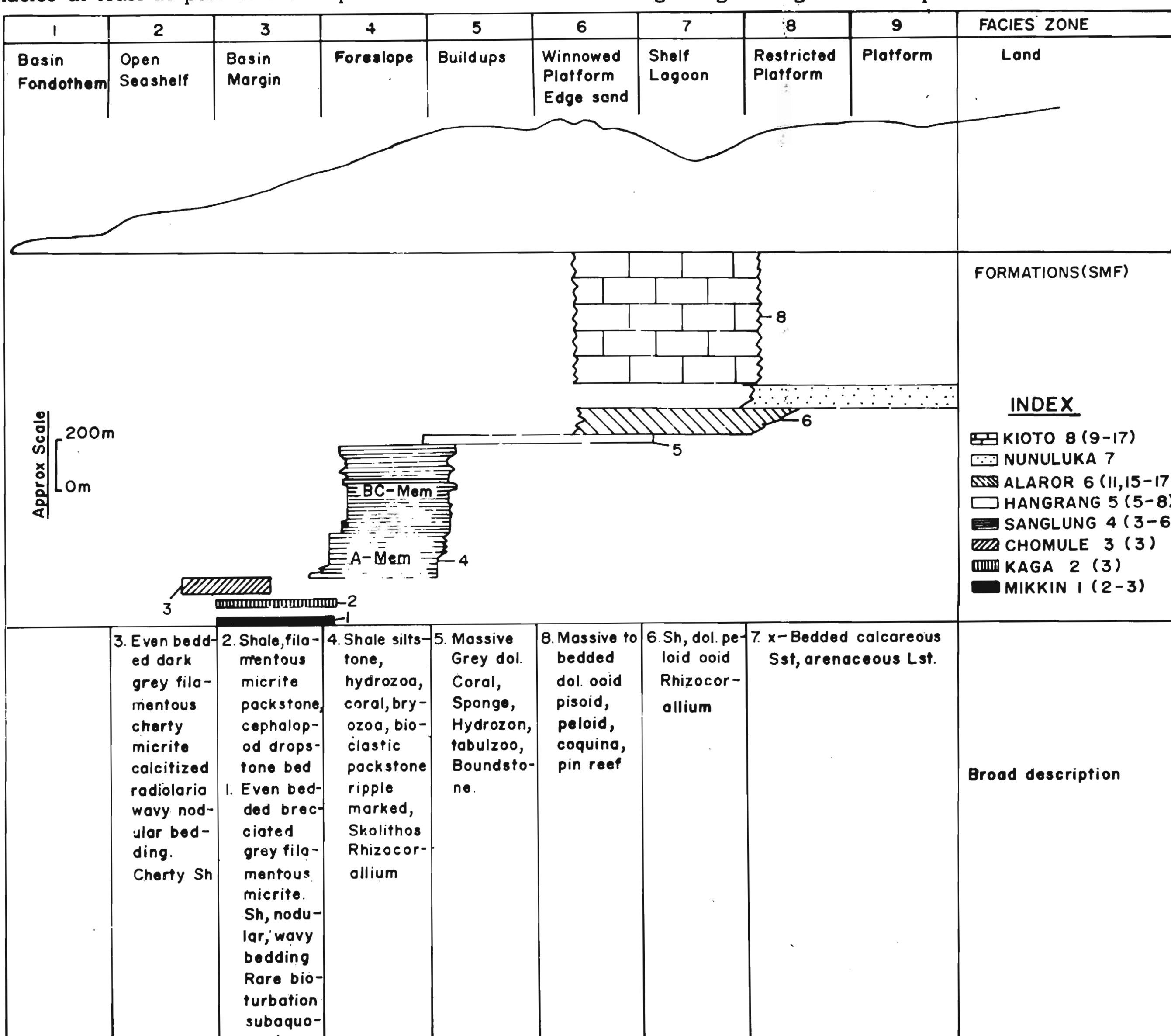

Fig. 3. Palaeoenvironmental location of various formations of the Lilang Group along an idealised basin profile drawn after Flugel (1982), SMF (Standard Microfacies) After Wilson (1975)

not withstand the rough sea condition and got destroyed. The Hangrang Formation with boundstone facies represents a true buildup. Its palaeoenvironments in space varied from fore, organic to? back reef, with local logoonal (Kiomo) areas (Bhargava and Bassi 1985).

4. Winnowed Platform Edge Sand to Shallow Shelf Lagoon: The Alaror Formation encloses mudstone, shoal bivalve ooidal grainstone/packstone with ooidal hydrozoan bindstone. The microfacies assemblage shows shoaly conditions in winnowed platform edge sand and shallow langoonal areas. Occurrence of *Rhizocorallium* in this formation possibly indicates protected nature of the lagoon.

5. Coastal to Estuarine Areas: The Nunuluka Formation comprising cross-bedded sandstone with superficial ooids, cortoids and dasyclad remains indicates a further regression to intertidal sandflat of a coastal area, adjoining or overlapping the restricted platform of a carbonate complex.

6. Winnowed Shelf Edge Sand to Shallow Shelf Lagoon: (a) The Para Member mainly comprises bioclastic ooidal, peloidal and oncoidal aggregate grainstone/packstone/wackstone with abundant megalodontid shells and quinqueloculinids. These microfacies along with megalodontids are typical of winnowed shelf edge sand ara (Wilson, 1975; Flugel, 1982). In the tidal channels of restricted platform, peloids, ooids and forminifera together with sparite were deposited (Pl 4/1, 5/7), (b) The Tagling Member shows megalodontids, shell-hash packstone, occasional nerinid grainstone and *Thecosmilia* pin reef which are characteristic of winnowed shelf edge sand and shallow undathem areas (Wilson,, 1975, Flugel, 1982). The glauconitic ooidal packstone/grainstone perhaps represents a sedimentological break and formation of hard ground followed by submergence to shelf mud when the upper Jurassic black Spiti Shale were deposited.

The palaeoenvironmental reconstruction of the Lilang Group reveals a gradual shallowing of the basin from the basin margin during the Mikin-Kaga periods to the coastal-estuarine area during the Nunuluka period, thus representing a regressive cycle. The shallowing from the rudstone enclosing Sanglung Formation upwards seems to be due to rapid rate of sedimentation which exceeded the rate of subsidence.

A transgression is registered by the Kioto Formation from the coastal areas of the Nunuluka time to the winnowed shelf edge sand area. This transgression caused onlap, resulting in the depostion of the Kio over the older formations in several sections (Fig. 1). This transgression is best documented in the Phipuk area where the Kioto Formation directly rests over the Lower Carboniferous sequence. This late Triassic and early Liassic sedimentological break is correlatable with similar breaks encountered elsewhere in the world which have been explained by a sharp eustatic sea level fall across the Triassic-Jurassic boundary (Hallam, 1978). This fall in sea level perhaps was associated with tectonic disturbance manifested by Triassic flysch in Ladakh (Frank *et al*, 1986).

The sedimentological history of the Lilang Group is illustrated in Fig. 3.

The sedimentation of the Lilang Group carbonates

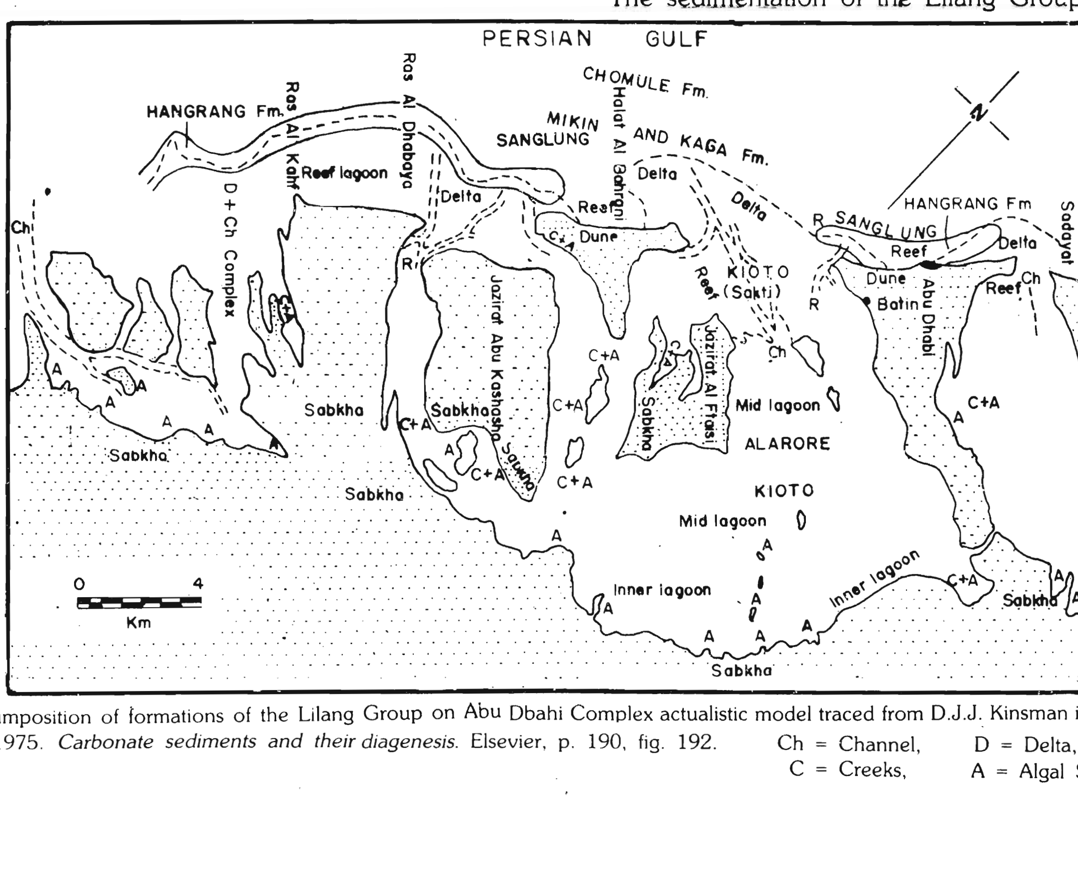

Fig: 4. Superimposition of formations of the Lilang Group on Abu Dbahi Complex actualistic model traced from D.J.J. Kinsman in R.G.C. Bathrust, 1975. *Carbonate sediments and their diagenesis*. Elsevier, p. 190, fig. 192. Ch = Channel, D = Delta, R = Reef C = Creeks, A = Algal Stromatolite can be broadly compared with the Persian Gulf actualistic basin around Abu Dhabi complex (Fig. 4) forming an arm of the Indian Ocean.

DIAGENETIC HISTORY

The Diagenetic history of the Lilang Group is largely interpreted after the criteria defined by Heckel (1983). The Mikin, Kaga and Chomule Formations have inconspicuous micritic cement. In burrows it varies from micritic to cloudy fibrous along rims followed by blocky in central part. The overpacked Mikin Formation in general and Kaga and Chomule Formations sporadically are characterised by laterally extensive stylolites. These indicate a connate environment with early cementaiton and later deep burial.

The cement in the A Member of the Sanglung Formation varies from inconspiouous micritic with laterally extensive stylolites, in the basal part to blocky, syntaxial and micritic in middle and upper parts. It shows variation from connate in basal part to meteoric phreatic environments in upper part.The cement in the Band C Members is syntaxial to micritic indicating mainly meteoric phreatic and mixed environments.

The Hangrang Formation shows varieties of cements (Bhargava and Bassi, 1985) varying from fibrous along rims to blocky in centre of cavities, micritic and syntaxial, showing diagenetic environment ranging in space from deep, marine phreatic to meteoric phreatic. The Alaror, Nunuluka and Kioto Formations have mainly blocky and equant sparitic cements with local drusy dog-tooth along rim and coarse sparitic in the Tagling Member, indicating meteoric phreatic to meteric vadose environments.

NATURE OF CONTACT BETWEEN THE PERMIAN KULING FORMATION AND THE LILANG GROUP

The ferruginous band occurring in the basal most part of the Mikin Formation has been often cited as evidence of brief sub-aereal exposure and hiatus. It is difficult to visualise that the Kuling basin was subaerially exposed for a short duration and resubmerged to shelf depth during the Scythian time, especially when there is no indication of any tectonic event during this period. This 'ferruginous' band has sharp contact with the underlying and overlying beds and cannot be described as subaerially formed pedogenised surface. This band is thus interpreted to represent Fe-Mn crust, though somewhat poor in Mn, to have formed during submarine unconformity. The rapid deepeining of the basin during Early Triassic is known from other parts of this Tethys also (Tollman and Kristan – Tollman, 1985).

PALAEOCLIMATIC RECONSTRUCTION

The basal Permian in the Spiti basin encloses cold water fauna represented by *Eurydensa – Deltopecten* assemblage (Ranga Rao *et al.*, 1984; Bhargava *et al*, 1985). In the basal Triassic except for grey-green coloured shale and siltstone in the Kaga Formation, which may indicate modestly cold temperature, no definite evidence for reconstructing the palaeoclimate is available. Warm-tropical conditions are possibly indicated during Norian when there was an extensive development of the coral reef in the Spiti-Ladakh areas.

PALAEOGEOGRAPHICAL LOCATION OF THE SPITI BASIN

The Spiti and Zanskar areas form one continuous synclinorium. It is separated from the Kinnaur-Kumaon synclinorium by a structural high. In view of comparitive litho and biofacies in Palaeozoic and Mesozoic rocks of these two synclinoria it is concluded that these two formed parts of the same basin. Along the northern part the sediments of this basin are thrust over by the Sangeluma Group (Srikantia and Razdan, 1980) along with ophilites which are also regarded as the melange of the Himalayan suture (Gansser, 1977, 1980). Some of these thrust masses occur much to the south as klippe in Ladakh (Fuchs, 1977; Srikantia and Razdan, 1981) and Kumaon (Heim and Gansser, 1939). Though the majority of the Lilang Group sedimental slopes facies, are recorded near Indus Suture Zone in Ladakh (Frank *et al.*, 1977). The Zanskar-Spiti-Kinnaur-Kumaon basin thus bounded by the Indus Suture in north is interpreted to have occupied a platformal, mainly passive marginal basinal position along the northern most part of the Indian Continental Plate, beyond which existed the open Tethys Sea.

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EXPLANATION OF PLATE

PLATE I

Scythian-Dogger Microfacies from Himachal Himalaya, India Except Fig. 10, (all negative prints)

1. Thin shelled molluscan wackestone/packstone containing whole thin shelled recrystallised cephalopods, chambers and interspace filled with thin shell fragments, a few crinoids. Mikin Formation. × 6.

2. Thin shelled nodular micrite. The Nodules are surrounded by laterally extensive micro-stylolites (stylobrecciated type) concentrating clay, Fe-Mn oxides. Shell fragments are of mollusca. Matrix light grey. Shell fragments may constitute more than 30% of rock. This facies is most wide spread in the Mikin Formation. × 4.5.

3. Juvenile cephalopod-micropeloidal packstone/grainstone with rock subsolution fragments filled with ?Fungi coated fossils. Matrix inhomogeneous (50% – 60% micrite, rest sparite), partly indigenous and partly difted off bank. Mikin Formation. × 3.5.

4. Layered thin shelled packstone and mudstone along planes of disconformity. The shells are aligned and broken, their layers have uneven surface. Thin shell fragments in mudstone layers. Rare sparite veins criss-cross the rock. Kaga Formation. × 6.

5. Graded thin shelled packstone/wackestone. Thin to medium thickness shells concentrated in bottom part, overlain by thin juvenile shells in a stylobrecciated fabric, occasional burrow. filled with ferro-material. Mikin Formation. × 6.

6. Bioturbated part filled with micrite and thin shell fragments. Mikin Formation. × 4.

7. Disconformity apparent due to uneven contact of thin shell fragments (bottom layer) with overlying layer containing adult shells. The overlying layers fill in the uneven portions of the underlying layers. Kaga Formation. × 4.

8. Thin shelled lithoclastic/bioclastic packstone showing fragments of lammellibranch, few echinids with dark rims and subangular to subrounded recrystallised sparite which could be organic debris. Cracks filled with sparite. Kaga Formation. × 4.

9. Cephalopod as dropstone within *Daonella* thin shelled layered packstone. The bottom layer shows sagging, those at cephalopod

level truncate against it, overlying thin shell layers are un-disturbed. *Daonella* which are nektonic/pelagic sank after death in a currentless basin. Kaga Formation. × 4.5.

10. Thin shelled wackstone/packstone with calcitised radiolaria and calcisphere. Mikin Formation. × 30.

PLATE II

Scythian-Dogger Microfacies from Himachal Himalaya, India (Except Fig. 1, 7 & 9. all are negative prints)

1-2. ?Calcitised radiolarian (*Dorydictyum,* Fig 1) wackestone with calcisphere. Except for uneven outline and a few spines no other feature of radiolarian is seen. Chomule Formation. Fig. 1. × 30. Fig. 2. × 25.

3. Thin shelled wackestone/packstone. Mikin Formation. × 25.

4. Lithoclastic/bioclastic grainstone/rudstone. Silt to fine sand well sorted homogeneous matrix. Bioclasts are (10%) of solanoporid, crinoid, bryozoa. Lithoclasts are angular to subangular, Fe-micrite and fragments of pre-existing packstone. 2% clasts are of quartz. Earlier cement around bioclasts syntaxial, late cement micritic. B Member. × 4.

5. *Seriastraea multiphyllia* SCHAFER & SENOBAR-DRAYAN in befflestone Hamrang Formation. × 4.

6. Thin shelled nodular micrite. Nodules surrounded by microstylolite (stylobrecciated) which have Fe-Mn oxides. It laterally passes into sandy floatstone (Pl 2/4). Cement minimal micritic. A Member. × 4.

7. Sandy floatstone having subrounded quartz (30% - 45%) in a ferronsparite matrix. The clasts are bivalves, coral and hydrozoan bindstone. Cement blocky sparitic. A Member × 4.5.

8. Bioclastic packstone/wackestone. Homogeneous dark brown matrix. Clasts are of bryozoa (A), echinid plates (B) and spine, crinoid ossicle, sponge, foraminifera and lamellibranch shells. Cement syntaxial and micritic. A Member. × 4.

9. *Thecosmilia clathrata* colony. Tagling Member. × 0.3.

10. Hydrozoa bindstone. In between space is filled by micrite, single, multilayered, simple and compound ooids and a few foraminifera. Cement not clear possibly micritic. C Member. × 5.

11. Lammellibranch grainstone/packstone. Matrix is sparitic with argillaceous material. Clasts are of lammellibranchs, crinoids. C Member. × 4.5.

PLATE III

Scythian-Dogger Microfacies from Himachal Himalaya, India (Except Fig. 7 & 8 all are negative prints)

1. Layered packstone/grainstone with four layers. The lower most (A) comprises hydrozoan fragments, it has a ferruginous coating indicating micro-disconformity. It is followed by *Colospongia* (B) aligned parallel to bedding plane, its chambers are filled with blocky sparite. Next layer (C) consists of broken or whole brachiopod shells. The top layer (D) shows well packed brachiopod debris with inhomogeneous matrix of sparite and micrite. Rare rounded, oval, and irregularly coated grains are also present. Hangrang Formation. × 2.

2. Coarse normal to well packed bioclastic packstone/grainstone. Matrix inhomogeneous varying from micrite to sparite. Clasts are micro-cephalopod (A), *Paradeningeria* (B), algal fragments, hydrozoans, echinoid spines, lamellibranch, gastropods. Hangrang Formation. × 3.

3. Well packed bioclastic cortoidal packstone. Homogeneous micritic matrix. Bioclasts of hydrozoans, brachiopods and echinoid spines. Cartoids micritic. Hangrang Formation. × 3.5.

4. Poorly sorted partially transported floatstone with clasts of *Thamnasteria rectlamellosa* WINKLER (A) ?*Cladocoropsis* (B), encrusted by a sponge (C), bryozoa (D), gastropod. Hangrang Formation. × 2.5.

5. Well to moderately sorted oolitic packstone with normal and compound ooids. Some ooids have truncated ooids as nucleus. A few ooids show fibrous cement of earlier generation. Gastropod clasts also occur. Cement sparitic blocky/equant. Hangrang Formation. × 3.

6. Layered mudstone with ?tempestite layer of gastropod, lamellibranch and ostracode. Cement not clear. alaror Formation. × 3.5.

7-8. Oolitic grainstone showing truncated ooid, radiating ooid and also concentric ones showing transport from quiet to agitated conditions. It also contains pellets, ostracodes, forminifera and sparite. Cement sparite blocky to equant. Tagling Member. × 25.

9. Shoal bivalve ooidal grainstone/packstone having sparitic homogeneous matrix (40% - 60%), shells (30%), ooids and a few dasyclads, all with dark rims. Ooids have quartz as nucleus, mostly single layered. Equant calcite cement. Alaror Formation. × 6.

PLATE IV

Scythian-Dogger Microfacies from Himachal Himalaya, India

1. Bioclastic wackstone/packstone with tidal channel, deposit. Matrix grey to palish brown micritic (percentage variable). The bioclasts are bivalve partly filled with peloidal mud, ooids. Coarse microcoproloid, foraminifera form nuclei for ooids occur in equant Fe-sparitic cement in the tidal channel. Within the channel the clasts are mostly confined to the bottom part. (Negative Print). para Member. × 4.5.

2.-3 Foraminiferal-peloidal grainstone/packstone. Foraminifera have dark ferruginous coating. Cement sparitic blocky/equant. Para Member. × 40.

4. Peloidal-lithoclastic aggregate grainstone. Well sorted micritic clasts, rounded, rod-shaped, dark-rimed (80%), dark rimmed sparite (2%), bioclasts (10%-15%) of forminifera (quinquloculinids), gastropod, echinoid, algae, bivalve., aggregate grains. Cement spartic blocky. (Negative Print) Tagling Member. × 5.

5. Enlargement of Fig. 3 showing ooids and bioclasts in a flask shaped aggregate grain enclosed in an ?algal sheath. × 22.

6 & 11. Peloidal foraminiferal packstone/grainstone. Forminifera represented by ?*Diplotremina* and some biseral forms (Fig. 11). Cement sparitic blocky equant. Tagling Member. × 25.

7. ?Foraminifera in glauconitic ooidal packstone/grainstone upper most part of the Tagling Member. Enlargement of Pl 4/7. × 75.

8. Compound ooidal aggregate grain packstone/grainstone showing ooid and echinoid spine enclosed in an ?algal sheath. Cement sparitic. Alaror Formation. × 25.

9. Sandy ooidal-algal grainstone. Moderately sorted angular to rounded coarse quartz, superficial ooids, a few radiating ooids, cortoid and iron coated dasyclad in a turbid sparitic cement

(30%). (Negative Print). Nunuluka Formation. × 4.5.

10 Oolites of earlier generations forming nucleus for compound ooids in a packstone/grainstone of micritic matrix. Cement sparite, blocky. Alaror Formation. × 25.

PLATE V

Scythian-Dogger Microfacies from Himachal Himalaya, India (Except Figs. 6-7, all are negative prints)

1. Normally to well packed nerinid ooidal packstone/grainstone enclosing multilayered radiating oolites occuring in between and within the chambers of nerinids. Other bioclasts are of *Pinacophyllum*, biserial foraminifera with dark rims. Cement is blocky in the burrows. Tagling Member. × 3.
2. *Thecosmilia clathrata* framestone corals are partly mud filled. Inter-space is filled by dark peloidal micrite and dark micritic matrix. Ostracode and a few gastropods occur as dweller. Ostracode test is also partly filled with peloidal material. Cement in open space is (i) fibrous along the cavity lining and blocky in central part. Tagling Member. × 4.
3. Peloidal/aggragate grainstone/bioclastic/lithoclastic floatstone/ packstone. Matrix (40%-60%) micritic, peloids are of different shapes and sizes, a few aggregate grains with sieve structure, bioclasts are of bivalves, foraminifera, algae, lithoclasts of sparite and pre-existing peloidal wackestone. Para member. × 5.
4. Normally packed bioclastic grainstone. Skeletal remains are of bivalve, bryozoa, ostracode, echinoid. Lithoclasts are of aggregate grains. Most of the clasts have dark rims. Cement sparitic blocky. Tagling Member. × 5.
5. Shell-hash packstone with abundant micritic matrix (40%-50%). Encloses silt/fine sand-size quartz replaced by calcite. Shells show umbrella effect with sparite cement in voids. Other clasts are of echinoids and a few radiating oolities. Burrows are filled with micrite and smaller clasts, Cement blocky. Styloites high to low peaked. Tagling Member. × 5.
6. Concentric, radiating, simple and compound oolites aggregate grains and recrystallised bioclasts. Cement spartic. Tagling Member. Enlargement of part of 1/5. × 25.
7. Enlargement of Pl 5/1, showing ?micro-coprolite as shapeless peloids, sparite fragments, biserial foraminifera forming nuclei of single layered oolites in sparitic cement. × 50.
9. Glauconitic packstone/grainstone with distorted oolites and foraminifera. Upper most part of the Tagling Member. × 50.

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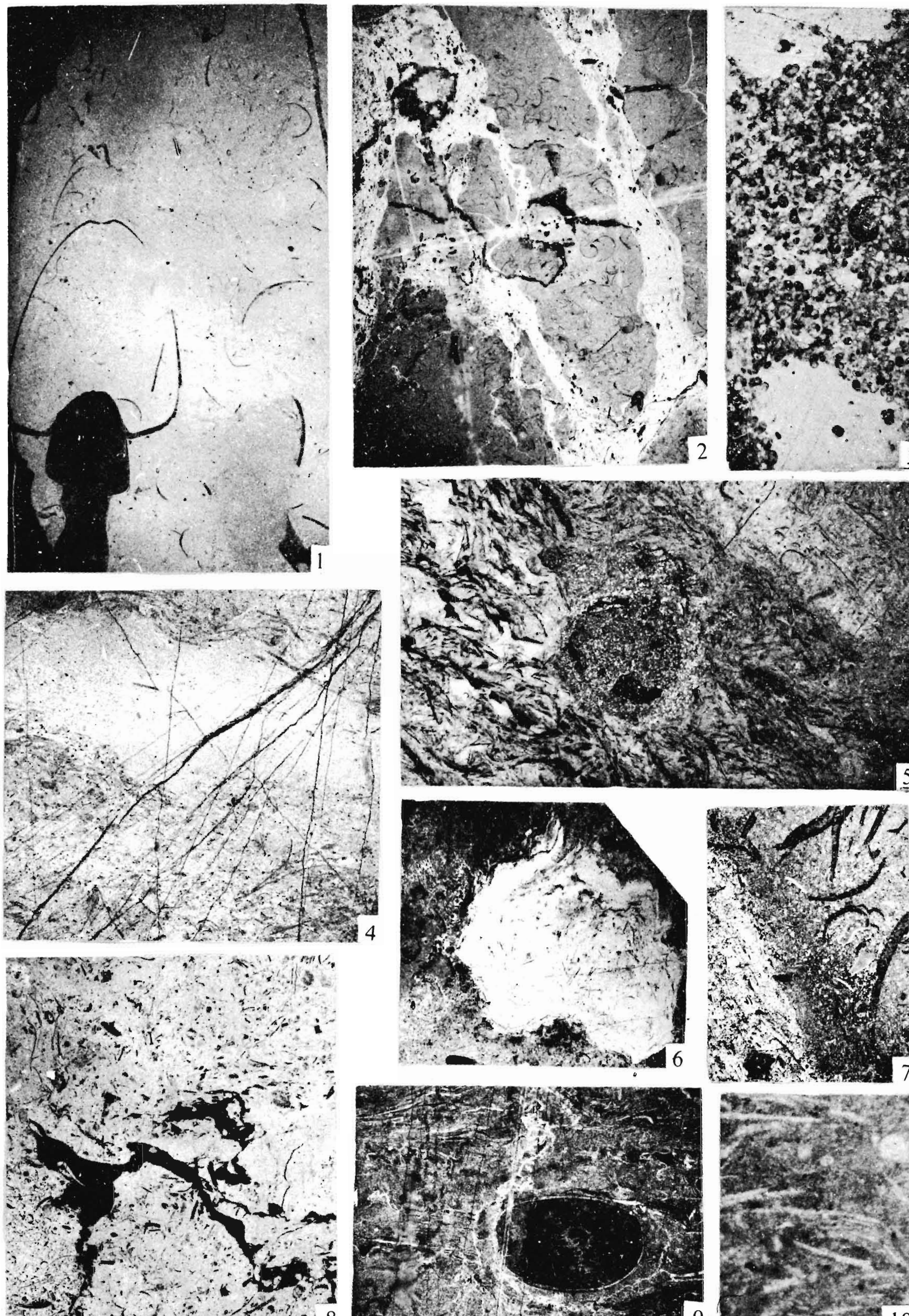
Plate I



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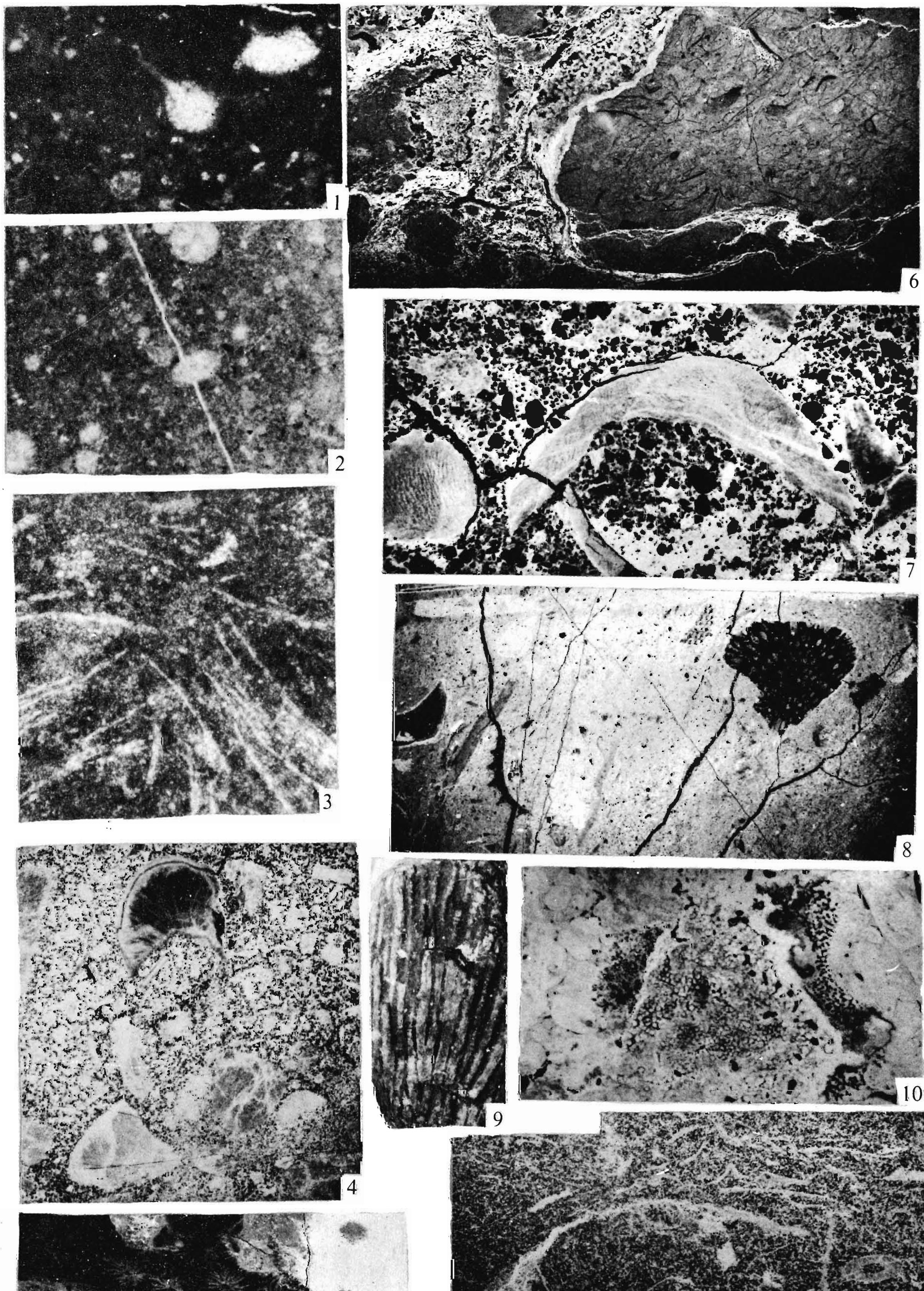

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Plate III

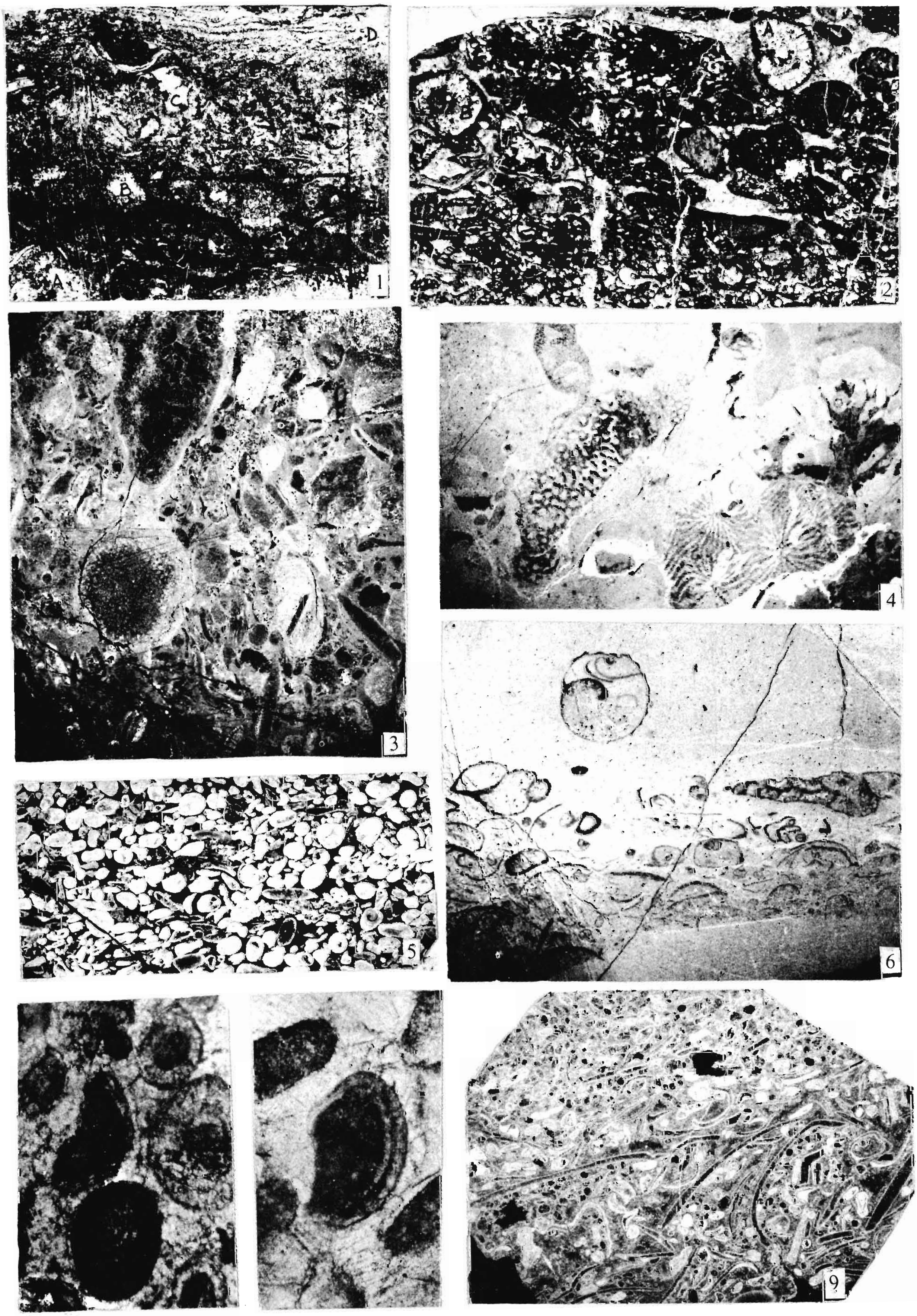

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Plate IV

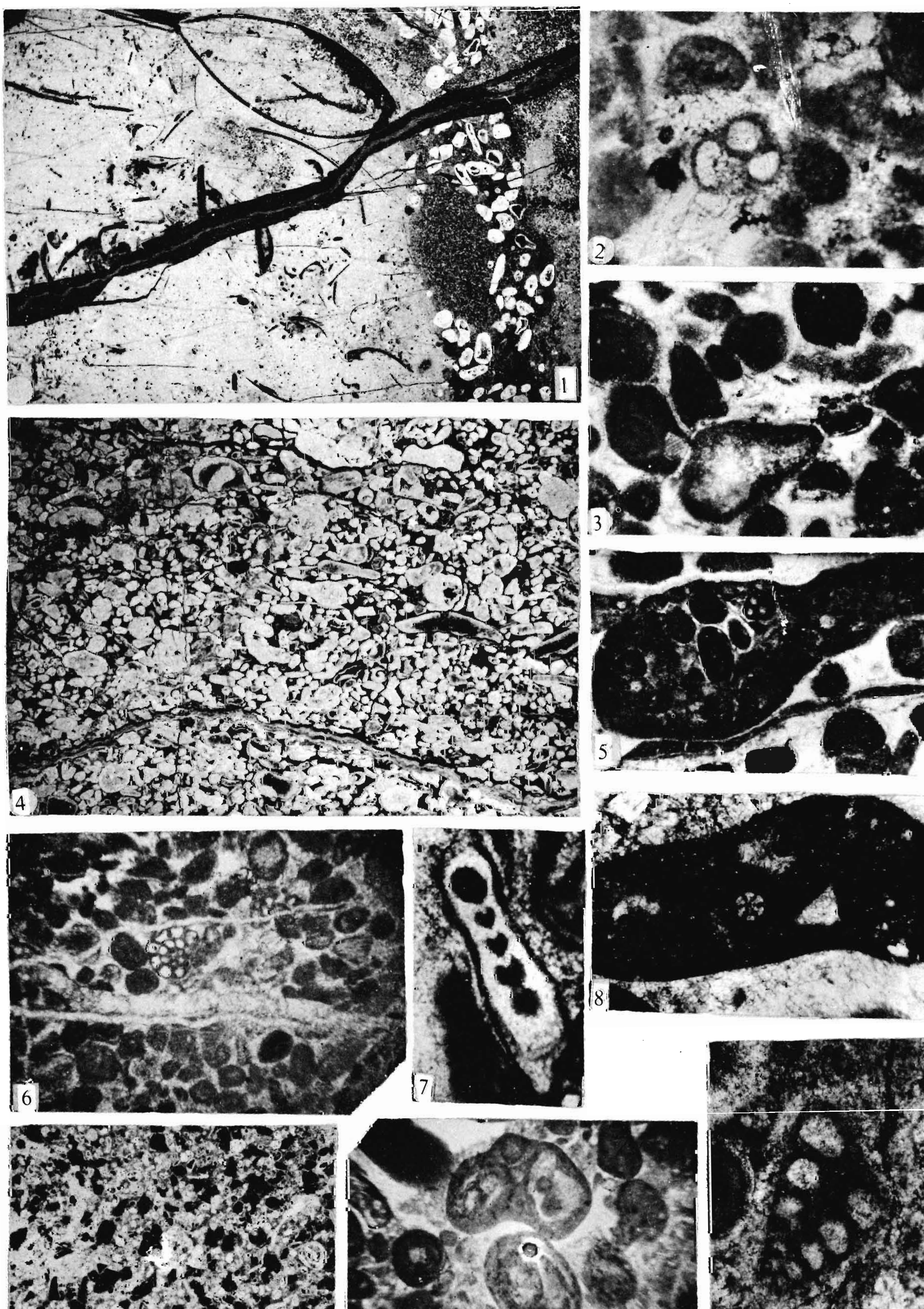

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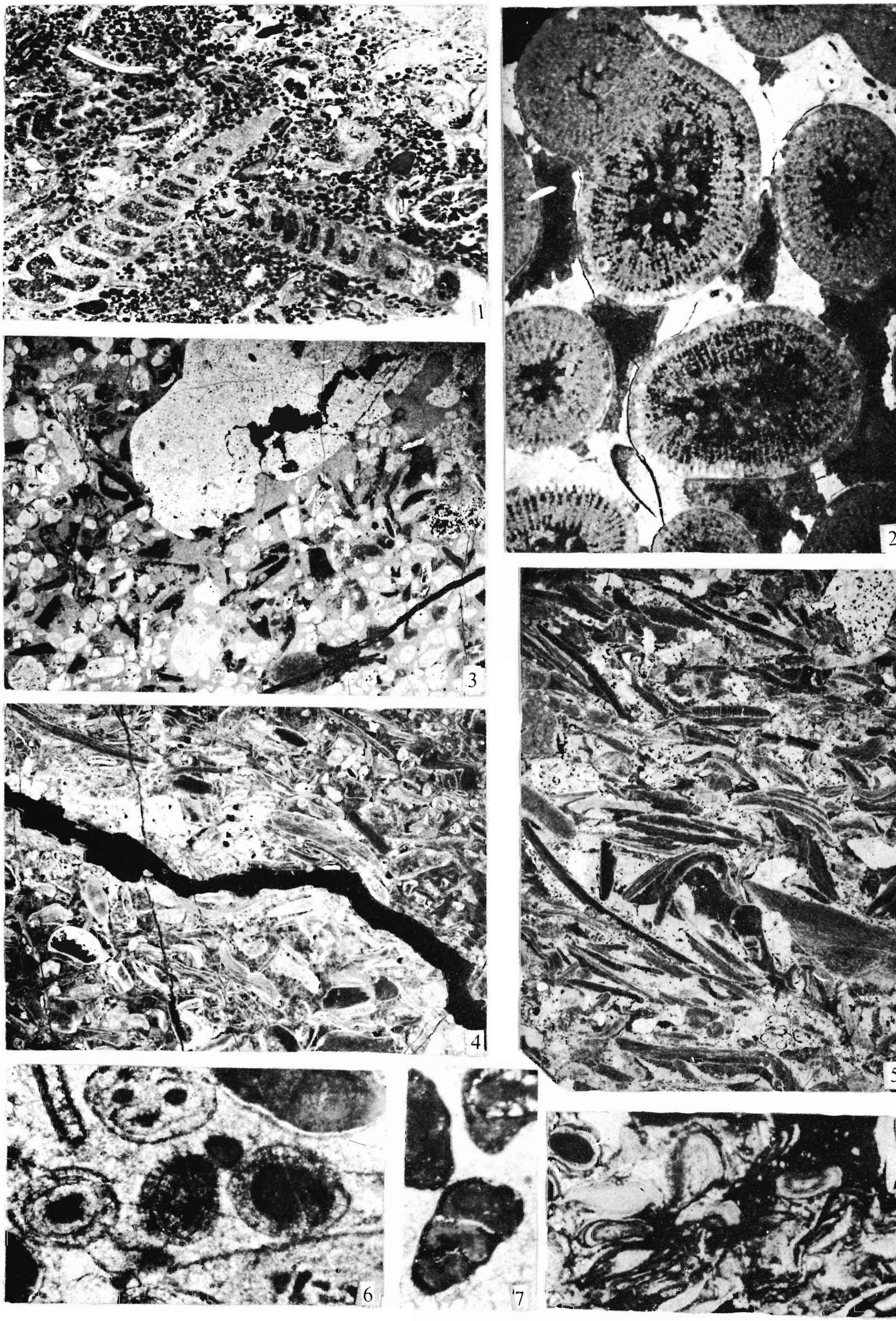
Plate V



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