Journal of The Palaeontological Society of India
Vol 40, 1995, pp. 55-76

STRATIGRAPHY AND PALYNOLOGY OF CARBONIFEROUS-PERMIAN - TRIASSIC SUCCESSION IN SPITI VALLEY, TETHYS HIMALAYA, INDIA

*TRILOCHAN SINGH, **R.S. TIWARI, **VIJAYA & **RAM-AWATAR
* WADIA INSTITUTE OF HIMALAYAN GEOLOGY, DEHRA DUN - 248 001
** BIRBAL SAHNI INSTITUTE OF PALAEOBOTANY, LUCKNOW - 226 007

ABSTRACT

The present paper is based on an extensive field work in Spiti Valley, to understand the regional relationship of various lithounits in Carboniferous-Permian-Triassic succession. The sequences worked out for their stratigraphy include Takche section, Mandaksa section and Ganmachidam Hill section in Upper Spiti Valley; and Lingti Hill section, Lingti Road section near the confluence of Lingti River with Spiti River, and Poh Hillock section in Lower Spiti Valley. In view of present field observations, the stratigraphic status of some lithounits, such as Ganmachidam Formation, Kuling Formation, Gechang and Gungri Members, is discussed. It is suggested that Ganmachidam Formation be placed under the Permian; the stratigraphic status of Kuling Formation be raised to the Group and those of Gechang and Gungri Members to the Formation level.

The rock samples from these strata are analysed for palynological studies. Recovery of spores-pollen is poor; generally the forms are dark brown in colour, along with few hyaline specimens. The taphonomic observations on palynomorphs reflect high diagenetic factors and reducing depositional environment. The qualitative assessment reveals the occurrence of *Parasaccites, Densipollenites, Faunipollenites* and *Crescentipollenites* in Permian sequence represented in Mandaksa Nala, Ganmachidam Hill, Lingti Road and Lingti Hill sections (Ganmachidam, Gehang and Gungri formations). The limestone-shale in the lower part of Lilang Group, in Lingti Road and Lingti Hill sections, have yielded the Early Triassic elements, viz., *Lundbladispora, Krempipollenites, Arcuatipollenites.*

A thin but continuous ferruginous layer is present above the black shale of Gungri Formation and below the limestone-shale unit of Lilang Group. This appears to be a marker bed representing the Evento-stratigraphic boundary. As far as the P/Tr boundary is concerned, the Gungri Formation has yielded typical Permian brachiopods and palynomorphs, and the limestone-shale unit of Lilang Group, referred to as the *Otoceras-Ophiceras* bed, has yielded Triassic cephalopods (*Otoceras, Ophiceras,* etc.), bivalves (*Claraia*), conodonts (*Gondolella, Neospathodus, Anchignathodus*), and palynomorphs. However, the top 1.30 m sequence of Gungri Formation is unfossiliferous, and thus, becomes important for the datum line of P/Tr boundary. Does this level correspond to Dorashamian / Changxingian to make the complete succession from Djulfian Stage of Permian to Griesbachian Stage of Triassic?

INTRODUCTION

The Spiti Valley, popularly known as the cold desert, is a remote part of Himachal Pradesh in the North-Western Himalaya, that lies between longitude 77° 38′ : 78° 36′ E and latitude 31° 42′: 32° 29′ N, covering an area of nearly 7500 sq km. The altitude of the area ranges from 3200 m to 6500 m. It is bounded in the north by Ladakh District of J & K, in the south by Kinnaur District of Himachal Pradesh, in the east by Tibet and in the west by Lahaul Valley and Kulu District of Himachal Pradesh (fig. 1).

The Spiti Valley forms a part of the Spiti-Zanskar Basin that belongs to the geotectonic zone of the Tethyan Himalaya. The basin is bounded by the Indus-Tsangpo Suture Zone (ITSZ) in the north and metamorphic basement of the Central Crystalline in the south. Structurally, the elongated Spiti Valley strikes parallel to the general trend of the Himalaya which is northwest- southeast. The first account on the geology of the area was given by Stoliczka (1865). Subsequently, Greisbach (1889) visited the valley and correlated the rocks of Spiti with those of Kumaun. However, Hayden (1904) was the first to give a comprehensive and systematic geological account of the Spiti area, establishing the complete sequence from Cambrian to Cretaceous in this area. The fauna and flora from Carboniferous-Permian-Triassic horizons were later described by Diener (1899, 1909, 1912, 1915), Gothan and Sahni (1942), Hoeg *et al.* (1955), and Tewari (1959). In recent years, general stratigraphy

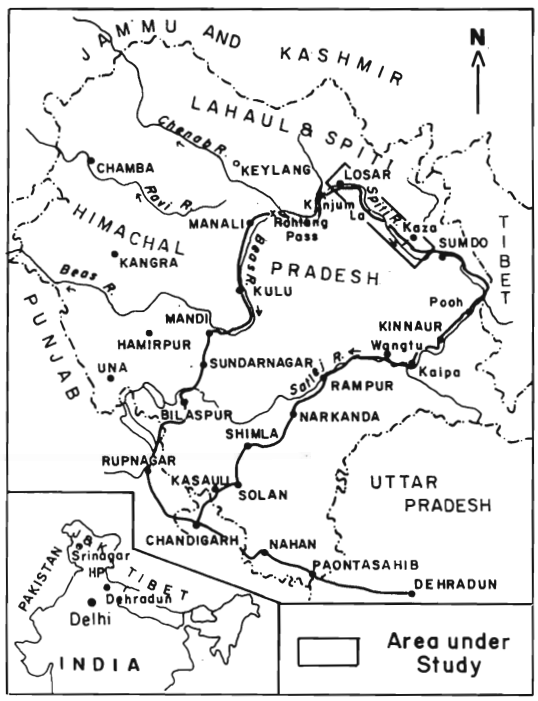


Fig. 1. Location map of the area.

and structure of the Spiti Basin, particularly related to the present interest, have been dealt by Srikantia (1981), Ranga Rao *et al.* (1984), Bhargava (1987), Bhargava and Bassi (1988), Bhargava and Gadhoke (1988), Bhargava *et al.* (1985a, 1985b, 1991) and Bagati (1990). Similarly, Goel (1977, 1982), Bhatt and Joshi (1978a, 1978b, 1981a, 1981b), Bhatt *et al.* (1980, 1981a, 1981b) and Bhatt and Arora (1984) contributed towards the biostratigraphy based on micro- and mega- fossils, whereas Khanna and Tiwari (1983) dealt with the miospores. The present interest in Spiti Valley is confined to the Carboniferous, Permian and Lower Triassic successions, with the following objectives : i) to prepare the lithostratigraphic columns in different sections to understand the regional and lateral relationship of these litho-units, and ii) to study the palynoflora to throw some light on the P/Tr boundary.

GEOLOGICAL SET-UP

The Spiti Valley offers a remarkably thick sequence of sedimentary rocks (Plate 1, fig. 1) resting upon Precambrian Crystalline Basement. The generalised lithostratigraphic succession of the Spiti Valley is given in Table 1. The distribution of these sediments in the Spiti Valley is shown in fig. 2.

Table 1 : Stratigraphy of the Spiti Basin (after Srikantia, 1981; partly modified)

Age	Group	Formation	Member	Lithology
Quaternary				Scree Terraces Glacial Erratics River Terraces Glacial Moraines
Cretaceous	Kibber	Chikkim	Shale	Greyish-yellow calcareous shale with thin limestone bands
			Limestone	Greyish-blue limestone
		Giumal		Calcareous sandstone, quartzite with lenses of limestone and interbeded black to olive green shale
Late Jurassic to Early Cretaceous		Spiti Shale		Black carbonaceous shale with small quartzite bands in the upper part
Jurrasic	Lilang	Simokhambda (=Kioto Limestone)		Massive to bedded greyish-blue limestone
Triassic		Alaror		Shaly limestone with sporadic lenticles of quartzite and shale
		Nimaloksa		Bedded to massive limestone with sporadic dolomite
		Hanse		Limestone with interbeds of greyish weathered calcareous shale
		Tamba Kurkur		Greyish-blue to dark grey bedded, limestone with greyish weathered shale
Permian	Kuling	Gungri		Carbonaceous shale and siltstone with concretionary nodules
		Gechang		Calcareous sandstone, quartzite and locally gritstone; grey needle/platy shale, gritty quartzite and quartzose sandstone
		Ganmachidam		Polymictic conglomerate, gritstone, and quartzitic sandstone
Carboniferous	Kanawar	Po		Quartzite with interbeds of black splintary shale and siltstone
		Lipak		Bluish grey limestone, dolomite, with interbeds of shale, pockets of gypsum
Late to Middle Devonian		Muth		Compact to friable mottled white Ortho-quartzite, with dolomite in upper part

Age	Group	Formation	Member	Lithology
Early Devonian to Late Silurian		Takche (= Pin Dolomite)		Ferruginous calcarenite, slate, dolomitic limestone and shale
Ordovician		Thango (=Shian Quartzite)		Interbedded purple quartzite and purple shale, siltstone, calcrenite, polymictite and sporadic dolomite
Cambrian to Precambrian	Haimanta	Kunzam La	E	Pink and brown quartzite, shale, slate, dolomitic limestone, siltstone, purple and green shale
			D	Olive green slate and flaggy quartzite with sporadic dolomite lenses
			C	Flaggy quartzite with slate partings
			B	Shale, slate, siltstone with quartzite
			A	Grey quartzite with slate partings
		Batal		Black pyritic carbonaceous slate and phyllite with quartzite, locally gritstone, and also olive green slate
Proterozoic	Salkhala			Mica schist, phyllite, quartzite, augen biotite gneiss with interfoliated migmatites
	Rohtang	Gneissic Complex		Gneisses, migmatites and metasediments
		Base not exposed		

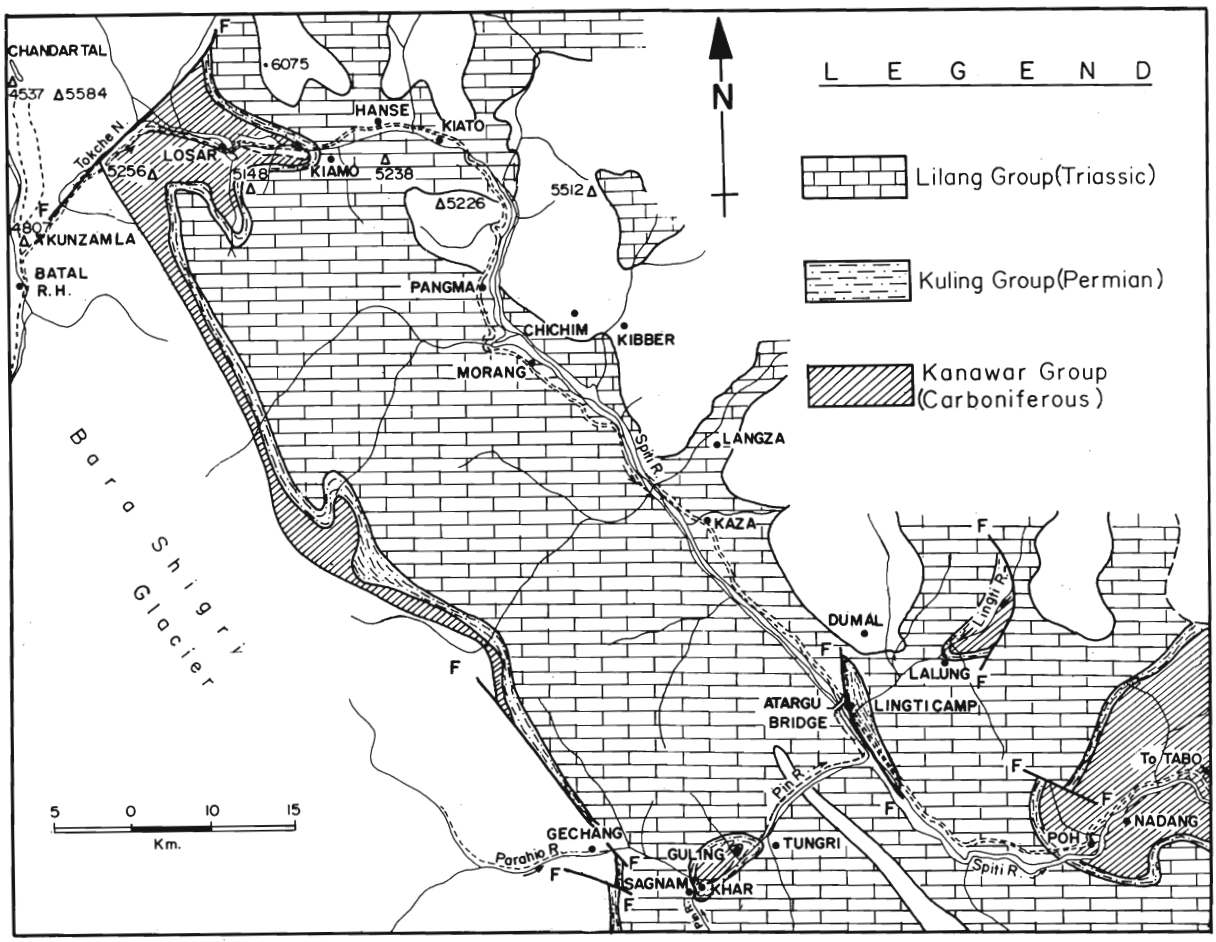


Fig.2. Sketch map of the Spiti Valley showing distribution of Carboniferous-Permian-Triassic lithounits (after Bagati, 1990).

LOCALITY AND MATERIAL

The present paper is based on the extensive field work carried out during 1990 to 1993 field seasons by one of the authors (TS). Another author (RA) accompanied him (TS) in 1993 field season. Traverses in the valley were taken and the following sections were worked out in detail : Takche Secton, Mandaksa Section, and Ganmachidam Hill Section near Losar (Plate 1, fig. 2) in Upper Spiti Valley; Lingti Hill Section (Plate 1, fig. 3), and Lingti Road Section near the confluence of Lingti River with Spiti River; Poh Hill Section near Poh Village, and Poh Hillock Section opposite Nadang Village (Plate 1, fig. 4) in Lower Spiti Valley; and Guling Section near Guling Village in Pin Valley. The lithological details and positions of the samples from different sections have been shown in litho-columns (figs. 3 a - g).

STRATIGRAPHY

The Permo-Carboniferous sequence is thick towards the north-western and south-eastern boundaries of the basin, but remains comparatively thinner throughout the major part of Spiti. In contrast, the Triassic succession is the thickest in the Spiti Basin and exists in almost all parts of the basin.

CARBONIFEROUS

The Carboniferous strata in Spiti were grouped under the "Kanawar Group" by Hayden (1904) who divided it into two series : Lipak Series and Po Series. Srikantia (1981), giving the status of Formation to these Series, also included the diamictites with associated quartzite and siltstone under the Kanawar Group and named this unit as the Ganmachidam Formation, representing the topmost Carboniferous sequence. The authors, however, prefer to include Ganmachidam Formation under Permian, as discussed in the subsequent text.

Lipak Formation

In general, it comprises fossiliferous limestone, sandstone, shale and gypsum. The limestone is argillaceous and often bears oolites and intraclasts. This litho-unit is best developed at Takche, and is also found near Losar.

The black limestone is the most dominant lithology of the Lipak Formation. At many places, the black limestone beds have orange-brown coating on the weathered surface. Bedded grey micrite limestone and crystalline limestone are also common. Grey shale and quartzitic sandstone occur as interbeds within the limestone. The most striking feature of the Lipak Formation of the Spiti Valley is the occurrence of gypsum as lenticular beds within the limestone sequence. Gypsum is snow-white in colour and powdery in nature. One such prominent bed can be seen on the road side, about 2 km from Takche towards Losar. Local people mine this gypsum for its use as building material.

Well - preserved sedimentary structures and trace fossils are commonly found. The siltstone within the shale showing cross-ripples and sand-layers with burrows are distinctly observed. Dark-grey, splintary needle shales contain abundant trace fossils. This limestone is fossiliferous mainly with corals and brachiopods.

Po Formation

It represents a contrast lithological association to the Lipak Formation, and comprises a sequence of interbedded quartzite and black carbonaceous shale with siltstone (Plate 1, fig. 4). The rocks of the Po Formation are well developed around Poh Village, after which the Po Formation has been named. It also occurs in Ganmachidam Hill and Mandaksa sections.

The black carbonaceous shale is splintary in nature. At places is pyritous. The carbonaceous shale is black to dark buff-grey in colour, lustrous in appearance and contains a few phosphatic nodules. A few shale bands show nodular weathering. Thin beds of silty sandstone occur within the shale. A few beds of shale are rich in *Fenestella*, as can be seen in Poh Hill Section. The silty sandstone also contains bryozoa and brachiopods. The quartzite is generally greyish-white to dirty-white in colour with generally brownish and greenish-grey tints; it often contains intercalation of calcareous slaty shale. Towards the top part, the quartzite dominates and becomes gritty and conglomeratic. The quartzitic sandstone is mostly laminated and contains ripple marks and cross bedding. At places the quartzite is calcareous, massive, often showing fracturing. In Poh Hill Section quartzitic sandstone, intercalated with shale, shows pinch and swell structure (Plate 1, fig. 5). The dark-greyish laminated siltstone bands are more common in the lower part and contain plant fossils. These are observed in Poh Hillock Section. The dark-grey shale is mostly splintary in nature, but that of the thick bedded is also found often containing carbonaceous matter. Two distinct lithologies characterise this unit : a) the siltstone having parallel laminations and top surface invariably cross rippled, and b) cm-thin silty sand layers having burrows and trace fossils mainly *Skolithos* and Star Fish (Plate 1, fig. 6). These fossiliferous beds are well exposed on the slopes of the Ganmachidam Hill.

PERMIAN

The Permian sequence in the Spiti Valley was referred to as the "Kuling System" by Stoliczka (1865). Later, Lydekker (1883) used this term for the Permian

beds in Kashmir. Greisbach (1889), however, preferred to use the term "Productus Shale". But the term "Kuling" with suffix "Shale" or "Formation" once again gained its popularity. Srikantia (1981) subsequently divided Kuling Formation into two members, the basal Gechang Member and the upper Gungri Member.

A characteristic unit, comprising conglomerate and grit passing up into coarse calcareous sandstone or sandy limestone, lying in between the alternating beds of shale and quartzite of Po Formation and overlying black shale (= *Productus* Shale), was not given any separate identity by Hayden (1904). However, Srikantia (1981) gave it the status of a Formation and placed it under the Carboniferous. It may be noted that these beds, which comprise of dominantly diamictite, have been equated with the Talchir and Salt Range Boulder Beds of definite Permian age. Secondly, the worldwide glaciation phenomenon occurred at the base of the Permian and is marked by the diamictites, or in other words there is no record of the diamictites in Carboniferous. Thirdly, the conglomeratic nature continues upward in the overlying unit, viz. Gechang Formation, which has alternating layers of calcareous sandstone and conglomerate in its lower part. It is, thus, proposed to place the conglomerate unit, designated as Ganmachidam Formation by Srikantia (1981), under the Permian. The authors also prefer to raise the status of Gechang and Gungri Members of Srikantia (1981), to the status of a Formation, and, in turn, would raise the status of Kuling Formation to the Group.

Thus, the Permian sediments are grouped under the Kuling Group, which would include Ganmachidam Formation, Gechang Formation and Gungri Formation, in ascending order.

Ganmachidam Formation

It represents a characteristic litho-unit consisting of polymictic conglomerate, quartzite, siltstone and shale. Srikantia (1981) used a formal term Ganmachidam Formation for this litho-unit after the name of a hillock near Losar Village. This litho-unit is exposed throughout the Spiti Valley; however, the thickness varies from section to section. It has a good development in Ganmachidam Hill Section and Lingti Road Section, and is poorly represented in Guling and Poh sections.

The Ganmachidam Formation commences with diamictite (= polymictic conglomerate) having loosely dispersed clasts of grey and green quartzite, vein quartz, greenish slates, grey limestone and dolomite in a mixed sandy and argillaceous matrix. The clasts generally range in size from a few mm to two cm, though sometimes these are up to 8 cm in diameter. The clast percentage increases higher up in the sequence. The Ganmachidam section shows cyclic sedimentation. The polymictic conglomerate is overlain by massive brownish-white coloured quartzite with occasional vein quartz, followed by khakhi-grey shale. Upward in the sequence the black shale is overlain by a sequence of white, coarse-grained and gritty quartzite grading into the massive polymictic conglomerate. This topmost massive polymictic conglomerate contains clasts of larger size than those present in the basal polymictic conglomerate, and is more compactly packed. Current bedding and graded bedding is occasionally noticed in the quartzite. The quartzite is thinly laminated, white to purplish, and mostly brownish-white in colour. Recrystallisation of grains is also noticed at places. It is coarse-grained to gritty and often bears quartz veins. The quartzite is folded on the top part which is distinctly seen in Ganmachidam Hill Section.

Gechang Formation

The Gechang Formation derived its name after the Gechang Village in the Parahio Valley of Spiti and comprises coarse sandstone and calcrenite. The rocks of this formation are exposed in Ganmachidam Hill, Mandaksa, Lingti (both hill and road), Poh Hill and Guling sections.

The Gechang Formation consists of dominant sandstone with locally thin bands of shale. The sandstone is brown to greyish-brown in colour with white tints, also pale-greenish at places. It is coarse-grained and gritty at many places. It often becomes calcareous. The sandstone is cross bedded and ripple marked at most of the places, and often contains thin shale bands. There are several layers of grey, needle/platy shale, gritty quartzite and quartzose sandstone within the lower part of the formation. It has also alternating layers of calcareous sandstone and conglomerate. The upper part of the formation is mainly massive calcareous with a few layers of shale.

The calcareous sandstone often contains brachiopod and bivalve fauna. In Ganmachidam Hill Section, the fossils are abundant and form a coquiuna bed. Brachiopods, particularly productids and spiriferids, are common in sandy shale in Guling Section. The Gechang Formation has a sharp contact with the overlying Gungri Formation.

Gungri Formation

It is well exposed in Ganmachidam Hill, Mandaksa, Lingti (both hill and road), and Guling sections.

The Gungri Formation comprises black splintary shale and steel - grey siltstone. The siltstone is locally calcareous and micaceous, and alternates with non-calcareous black or steel - grey shale, which at most of the places becomes arenaceous, highly fossiliferous and

contains dark-grey phosphatic nodules (Plate 1, fig. 7). The nodules vary in shape and size, being mostly rounded, oval or elliptical, or rarely elongated and cylindrical. The size varies from a few cm to 1.5 m. Beside these, a few lenses or thin beds composed of concretionary nodules also occur within the black shale. At least two such beds are located in the black shale at about 7.30 m and 21.90 m from the top of the black shale, i.e., below the ferruginous layer in Lingti Road Section. The sandy shale in this section shows impressions of a typical structure and often contains fossils. In Ganmachidam Hill Section, a few sandy shales show pseudo-plant fossils.

Significantly, a thin but continuous ferruginous layer is observed on the top of the black shale of the Gungri Formation at Mandaksa, Guling and Lingti road sections. It varies from 3 to 8 cm in thickness.

TRIASSIC

The Triassic rocks of the Spiti Valley were referred to as the Lilang System (Stoliczka, 1865), which were regionally mapped by Hayden (1904) and subdivided into 15 biostratigraphic divisions by Diener (1912). Srikantia (1981) redesignated it as the Lilang Group and divided into five formations. Subsequently, Bhargava (1987) classified it into eight formations. The present interest, however, is restricted to the lower part of the Triassic succession.

Lilang Group

The rocks of this group covers a very wide area and are exposed on either side of the Spiti river, from Losar to Dankar. These are dominantly carbonates, having enormous thickness.

The field study shows that the overall lithology of the Lilang Group comprises limestone (often fossiliferous, argillaceous, oolitic and intraclastic) with interbedded, often calcareous shale, and quartzite. Higher up in the sequence shaly limestone, thin to thick bedded with lenticular quartzite and sandstone beds with calcarenites are present. The calcarenite shows cross-stratification. The topmost part is represented by massive greyish-blue limestone.

The basal part of the Lilang Group contains flaggy limestone with ferruginous chert and calcareous shale layers, having wavy and irregular bedding surface. The limestone is grey, greyish-black, black, greyish-blue in colour with minor shale partings. The shale is typically ash-grey in colour. Near the base, interlayering of shale and limestone is very thin, varying from 5 to 15 cms. The total thickness of this unit is 1.30 m in Lingti Road Section and 1.25 m in Guling Section. Bhatt and Joshi (1981 b) and Bhandari *et al.* (1992) have shown the thickness of this unit as 0.98 m and 1.15 m, respectively, in Lalung Section. This unit is referred to as the *Otoceras-Ophiceras* beds. These are overlain by alternation of thick shale and limestone beds. The thickness of individual shale and limestone bed gradually increases upward in the sequence. These beds also contain fossils, particularly the ammonoids. Nodular weathering is a common feature found in the limestone.

PALYNOFLORAL AND FAUNAL ASSEMBLAGES

During the last two decades, efforts have been made for the palynostratigraphic studies in Tethys Himalayan sediments but the recovery of palynofossils had been poor.

For the present study, the samples from the Permian and Lower Triassic sequences represented in five sections have been analysed. Symbols in lithocolums indicate Blank circle (Faunal yield); Filled circle (Palynofossil yield). A brief account of spore-pollen and faunal composition and their characteristics are given below for each section. The palynofossil slides have been stored in the repository of the Birbal Sahni Institute of

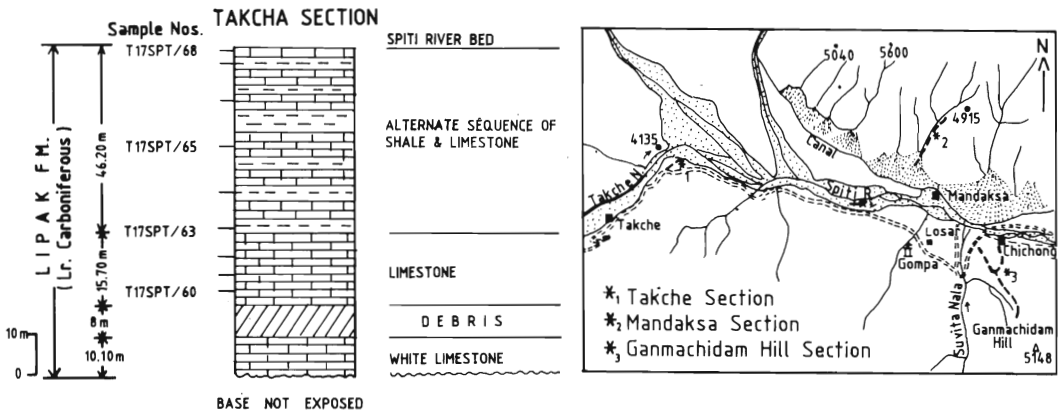


Fig. 3a. Takche Section–lithocolumn showing the lithology, thickness, stratigraphic location of the samples, along with location of the section measured.

Palaeobotany, Lucknow. The repository slide numbers are given in the explanation of plates.

Takche Section

This section was measured just near the confluence of Takche Nala and Spiti River at the open ground getting a little down from the road towards the Takche Nala (Fig. 3a). It exposes only the Lipak Formation, i.e., Lower Carboniferous. Nine samples for palynofossils were collected, but none was found to be productive. Although no faunal remains from this particular section were recorded yet corals, bryozoans, spiriferoids are known from the adjoining section, just across the Takche Nala.

Mandaksa Nala Section

The Mandaksa Nala Section (location shown in fig. -3a) could not be measured owing to slope-debris covering. However, reference samples (13 in nos, Table 2) could be collected from the available scanty outcrops,

Table 2: List of Samples collected from Mandaksa Nala Section, Spiti Valley, Tethyan Himalaya, (H.P.)

Sl. No.	Sample Nos.	Lithology	Age	Formation
1.	T17 SPT/1	Black splintery Shale	:	
2.	T17 SPT/2	Sandy Shale	:	
3.	T17 SPT/3	Sandy Shale	:	Gechang
4.	T17 SPT/4	Sandy Shale	:	Formation
5.	T17 SPT/5	Sandy Shale containing clasts	:	
6.	T17 SPT/6	Sandy Shale	:	
7.	T17 SPT/7	Grey Shale	:	
8.	T17 SPT/8	*Sandy Shale	Permian	
9.	T17 SPT/9	Shale	:	
10.	T17 SPT/10	Black Shale (15 m above from the sample no. 9)	:	Gungri Formation
11.	T17 SPT/11	Black Shale	:	
12.	T17 SPT/12	Black Shale	:	
13.	T17 SPT/13	Fossiliferous Shale bands	:	

Table 3 : Mandaksa Nala Section

Horizon	Formation	Productive Samples	Spore-Pollen	Taphonomic Observations	Fauna
Upper Permian	Gungri Formation	T17 SPT/10 *T17 SPT/11	*Densipollenites* sp. *Densoisporites* sp.		*Neospirifer* sp. *Productus* sp.
Lower Permian	Gechang Formation	T17 SPT/2, 3, 4, 5	*Verrucosisporites narmianus* *Jayantisporites pseudozonatus* *Dentatispora* sp. *Lacinitriletes badamensis* *Microfoveolatispora* sp. *Microbaculispora indica* *Parasaccites* sp. *Parasaccites obscurus* *Parasaccites korbaensis* *Potonieisporites neglectus* *Vesicaspora crassa* *Vesicaspora distincta* *Scheuringipollenites maximus* *S. tentulus* *S. barakarensis* *Vestigisporites notus* *?Sahnites* sp. *Faunipollenites varius* *Faunipollenites perexiguus* *Striatopodocarpites* sp. *Crescentipollenites fuscus* *Rhizomaspora* sp. *Leiosphaeridia* sp.	Dark brown, exine character distinct, black organic matter impregnated, specimens generally intact, rarely broken	

* - Sample yielded fauna

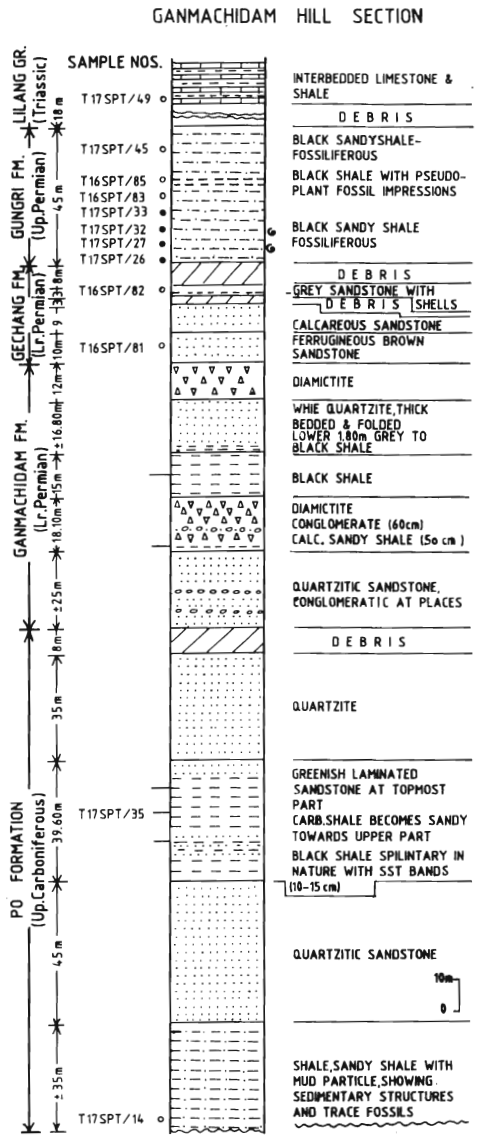


Fig 3b. Ganmachidam Hill Section, near Losar Village.

out of which five samples (T17 SPT/2, 3, 4, 5, 10) have been found to be productive in palynofossils. The details of the palyno-composition and their characteristic taphonomic observations determined from the qualitative estimation in the productive samples are given in Table 3. The representatives of the palyno-assemblage recovered in this section are shown in Plate II, figs. 1 - 18.

Remarks : The spores and pollen grains are intact; rarely broken specimens observed, but the exinal characters are, in general, distinct. The total composition recovered within the samples (T17SPT/2, 3, 4 and 5) are broadly comparable with the Lower Barakar palyno-assemblages of the Peninsular India (Tiwari, 1974; Tiwari & Ram-Awatar, 1988) in frequent occurrences of *Scheuringipollenites* and *Faunipollenites* species. Moreover, the specific diversity in sample T17SPT/2 is quite significant for the real assessment of palyno-composition at the base of the Ganmachidam Formation. In Sample No. T17SPT/10, representing the upper part of Permian sequence in this section, the yield is not satisfactory. The faunal occurrence is sporadic in this section.

Ganmachidam Hill Section

The Ganamachidam Hill Section (Plate I, fig. 2) was measured, atleast from its basal part on the two sides– one from Savita Nala side, and the other from Chichong village side. (location shown in fig. 3a). This section shows Upper Carboniferous (Po Formation), Permian (Ganmachidam, Gechang and Gungri Formations) and Triassic (Lilang Group) succession (fig. 3b). A total of 39 samples have been processed, out of which four samples (T17 SPT/26, 27, 32, 33) have yielded the spores and pollen. The palyno-composition and other characteristics, as derived from the qualitative estimation of spore-pollen taxa, are given in Table 4, and its representative taxa are shown in Plate III, figs. 1-14.

Remarks : The sandy shale of the Gungri Formation in this section, contains diversified group of palyno-fossils. The dominating elements are striate-bisaccate pollen, i.e., *Striatopodocarpites, Faunipollenites, Crescentipollenites.* Their comparability with the Upper Raniganj palynoassemblage (Tiwari & Singh, 1986; *R-IA*) is indicated by having striate-bisaccate pollen in prominence along with *Densipollenites* species, and the occurrence of cf. *Arcuatipollenites* and *Kamthisaccites.* The fauna occurs sporadically in Gechang Formation in its lower part, but becomes abundant higher up in the sequence. The faunal assemblage as a whole indicates Sakmarian to Artinskian age for this formation. Amongst the faunal assemblage of Gungri Formation, brachiopods dominate whereas bivalves and cephalopods are comparatively lesser.

Lingti Hill Section

This section was measured from the point about 100 m North West of Lingti Camp [defined as office of the Irrigation & Public Health (IPH)] towards the hill peak (Plate I, fig. 3), and hence this section is named as Lingti Hill Section. In this section the Permian and the Triassic successions are well developed (fig. 3c). Seven samples from this section have yielded palynofossils, of which four (T17 SPT/115, 116, 117, 118) are from Permian and three (T17 SPT/122, 124, 125) are from Triassic sequences. Four other samples (T 17 SPT/109, 110, 111, 114) have also yielded fauna in this section. The palynological composition as recovered from this sec-

Table 4 : Ganmachidam Section

Horizon	Group\ Formation	roductive Samples	Spore-Pollen	Taphonomic Observations	Fauna
Lower Triassic	Lilang Group	*T17 SPT/49	—	—	Ammonoids
Upper Permian	Gungri Formation	T17 SPT/26, 27, 32, 33	*Verrucosisporites* sp. *Densipollenites indicus* *D. invisus* *cf. Kamthisaccites kamthiensis*	Light yellow to dark brown, exine character distinct, grains rarely broken, glassy appeareance in few specimens, black organic debris attached on the specimens	*Spiriferella rajah* *Marginifera himalayensis* *Mourlonia* sp.
		*T17 SPT/45 *T16 SPT/ 83, 85	*Sahnites* sp. *Alisporites parvus* *Krempipollenites* sp. *Faunipollenites varius* *F. perexiguus* *Striatites parvus* *Striatopodocarpites decorus* *Crescentipollenites fuscus* *Distriatites bilateralis* *Weylandites indicus* *cf. Arcuatipollenites ovatus* *Faunipollenites perexiguus*		
Lower Permian	Gechang Formation	*T16 SPT/ 81, 82	—	—	*Eurydesma* sp. *Peruvispira* sp. *Linoproductus* sp. *Spirifer* sp. *Dielasma* sp. *Streptorhynchus* sp.

* - Sample yielded fauna

Table 5 : Lingti Hill Section

Horizon	Group\ Formation	roductive Samples	Spore-Pollen	Taphonomic Observations	Fauna
Lower Triassic	Lilang Group	T17 SPT/122, 124,125	*Verrucosisporites* sp. *Dicapipollenites* sp. *Striatopodocarpites* sp. *Arcuatipollenites pellucidus* *Densipollenites indicus* *Densipollenites invisus* *Crescentipollenites fuscus* *Faunipollenites varius* *Kraeuselisporites* sp. *Alisporites parvus* *Lundbladispora* sp. *cf. Chordasporites* sp. *Krempipollenites* sp.	Dark brown, exine characters not distinct; speciments intact	
Upper Permian	Gungri Formation	T17 SPT/115, 116, 117, 118	*Verrucosisporites bosci* *Verrucosisporites narmianus* *?Simeonospora* sp.	Black brown, exine characters indistinct, black organic matter impregnated, well preserved, generally intact	
		*T17 SPT/ 108, 109, 110, 111, 114	*?Lundbladispora* sp. *Densipollenites invisus* *Densipollenites* sp. *Goubinispora* sp. *Alisporites parvus* *Alisporites indicus* *Scheuringipollenites maximus* *Faunipollenites varius* *Striatites* sp. *Striatopodocarpites decorus* *Striatopodocarpites fuscus* *Striatopodocarpites* sp. *Crescentipollenites fuscus* *Rhizomaspora* sp. *Arcuatipollenites pellucidus*		*Spiriferella rajah* *Marginifera himalayensis* Chonetid, Bryozoans

* - Sample yielded fauna

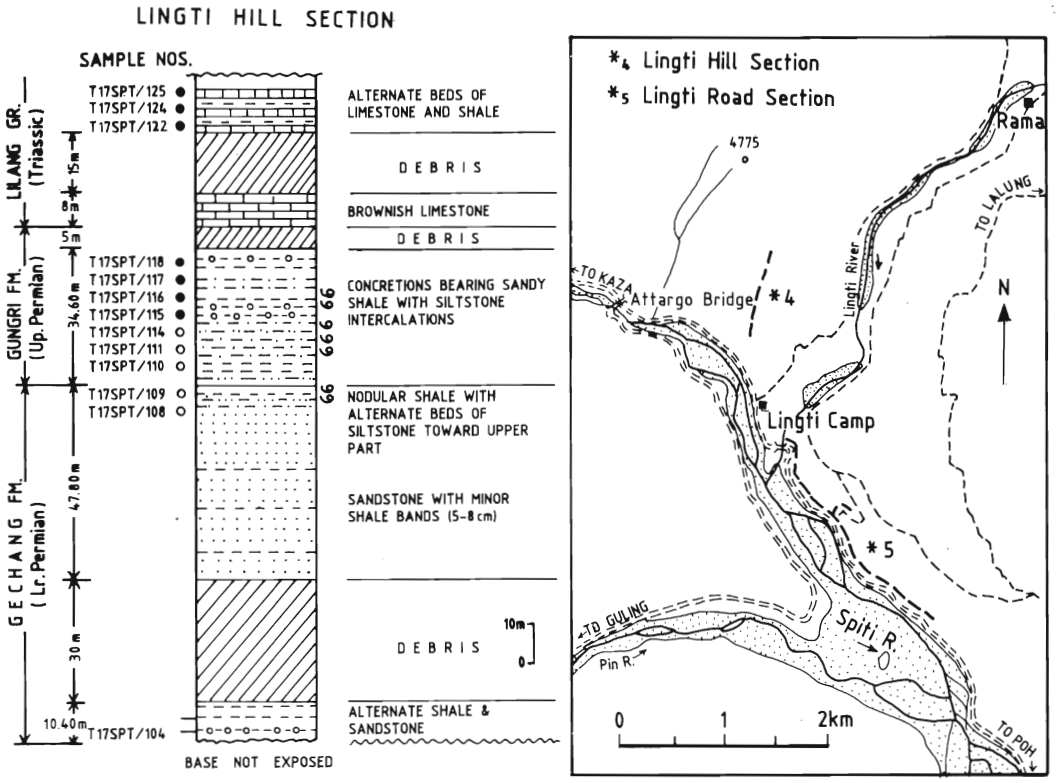


Fig. 3c. Lingti Hill Section, just north of Irrigation and Public Health Department Rest House.

tion is given in Table 5, and their representative taxa are shown in Plate IV, figs. 1 - 13.

Remarks : In general, the palynofossils are not distorted, and the composition in the samples of Gungri Formation is qualitatively diversified, comparable with the Raniganj palynoassemblage of Damodar Basin, India (Tiwari & Singh, 1986; *R-IA*). The most significant feature at this level is the record of Early Triassic elements, viz., *Lundbladispora* and *Arcuatipollenites* species. These taxa have been further observed in the overlying Lilang Group along with typical Lower Triassic taxa, viz., *Kraeuselisporites*, a typically northern element, *Alisporites*, and cf. *Chordasporites*. The faunal remains are abundant and distributed throughout the sequence. The fauna is found both in the nodules as well as in the shale.

Lingti Road Section

This is an important section because a continuous sequence from Permian to Triassic is exposed here (fig. 3d), which has helped to understand the sequence at the P/Tr boundary. Observations in this section start along the road from the bridge at Lingti River, towards Tabo (location shown in fig. 3c). Out of forty-three samples collected from this section, only six samples have been found to be productive palynologically (T17 SPT/86, 87, 101, 132, 133 and 135). The spore-pollen composition, as derived from the qualitative assessment and their characteristic features, is given in Table 6.

Remarks : Except few striate - bisaccate pollens, no other marker palynotaxa is observed in these two sequences. A broader aspect close to the Barakar palynoassemblage of the Damodar Basin for the age determination (Tiwari, 1974) may be suggested to the Gechang Formation, more particularly with Upper Barakar palynoassemblage. No definitive comment is possible for the Lilang Group palyno-composition. The fauna is abundant in this section, particularly in the Gechang Formation. The fauna of the Gungri Formation is significant and the size of specimens is comparatively smaller. The topmost level of occurrence of brachiopod is from the level about 2.85 m below the carbonate sequence of the Lilang Group.

Poh Hill Section

This section is located just north of P.W.D. Rest House at Poh towards the hill (fig. 3f). Although, Carboniferous to Triassic through the Permian are exposed in this section, the observations were confined only to the Carboniferous rocks represented by the Po Formation (fig. 3e). The Lipak Formation is not exposed in this section.

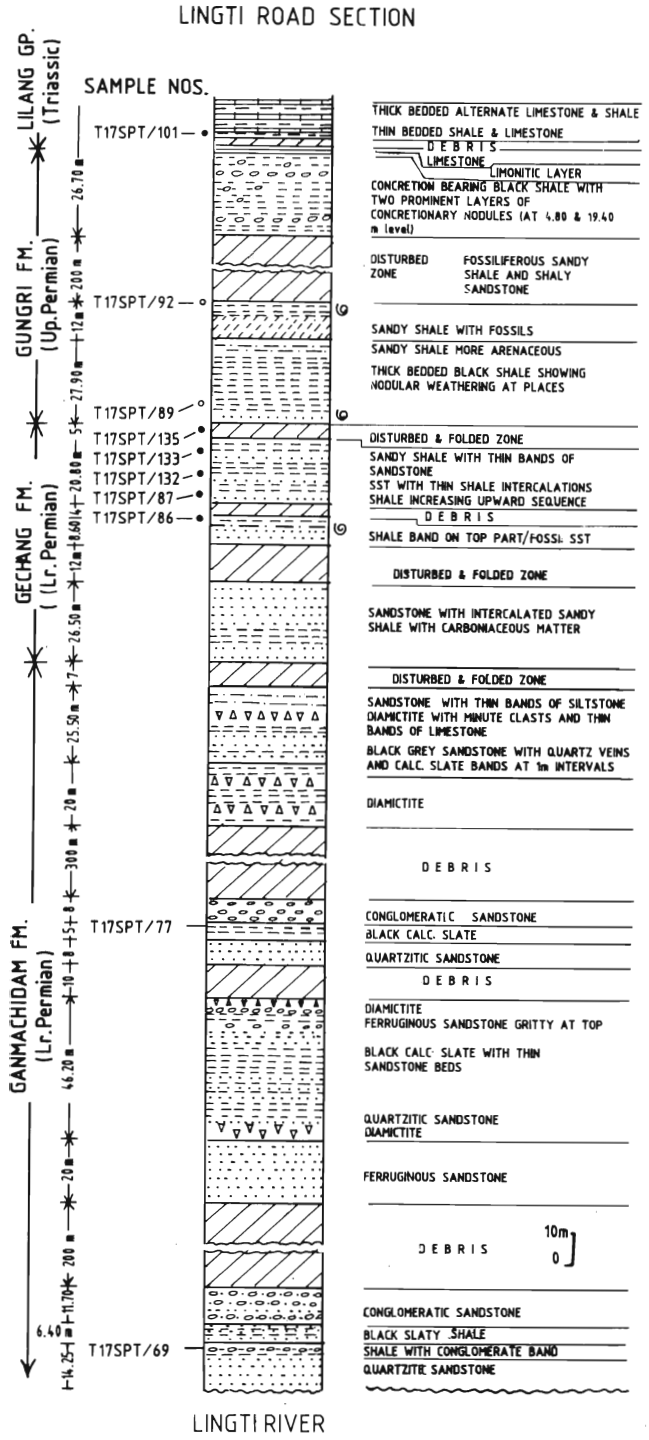


Fig. 3d. Lingti Road Section, from the bridge over Lingti River on Kaza-Tabo road towards Tabo. For location please refer to fig. 3c.

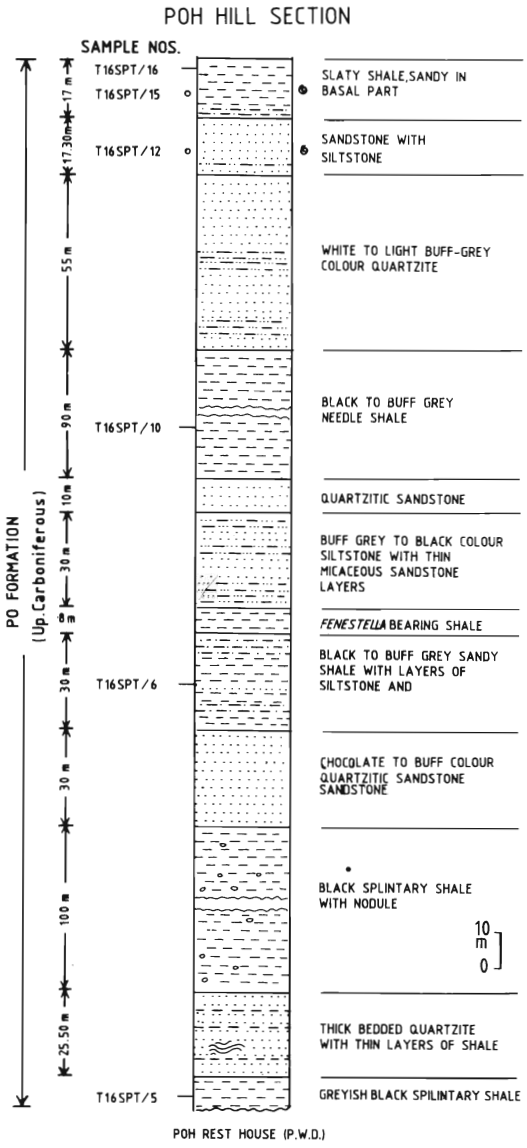


Fig. 3e. Poh Hill Section, just north-north-west of the P.W.D. Rest House at Poh. For location please refer to fig. 3f.

Remarks : The samples from this section subjected for chemical processing to recover the palynofossils proved barren. Hence, no record of playnofossils from this section. However, bryozoans were encountered. *Eurydesma* sp. is also known to occur in this section (vide Bhargava *et al.*, 1985b).

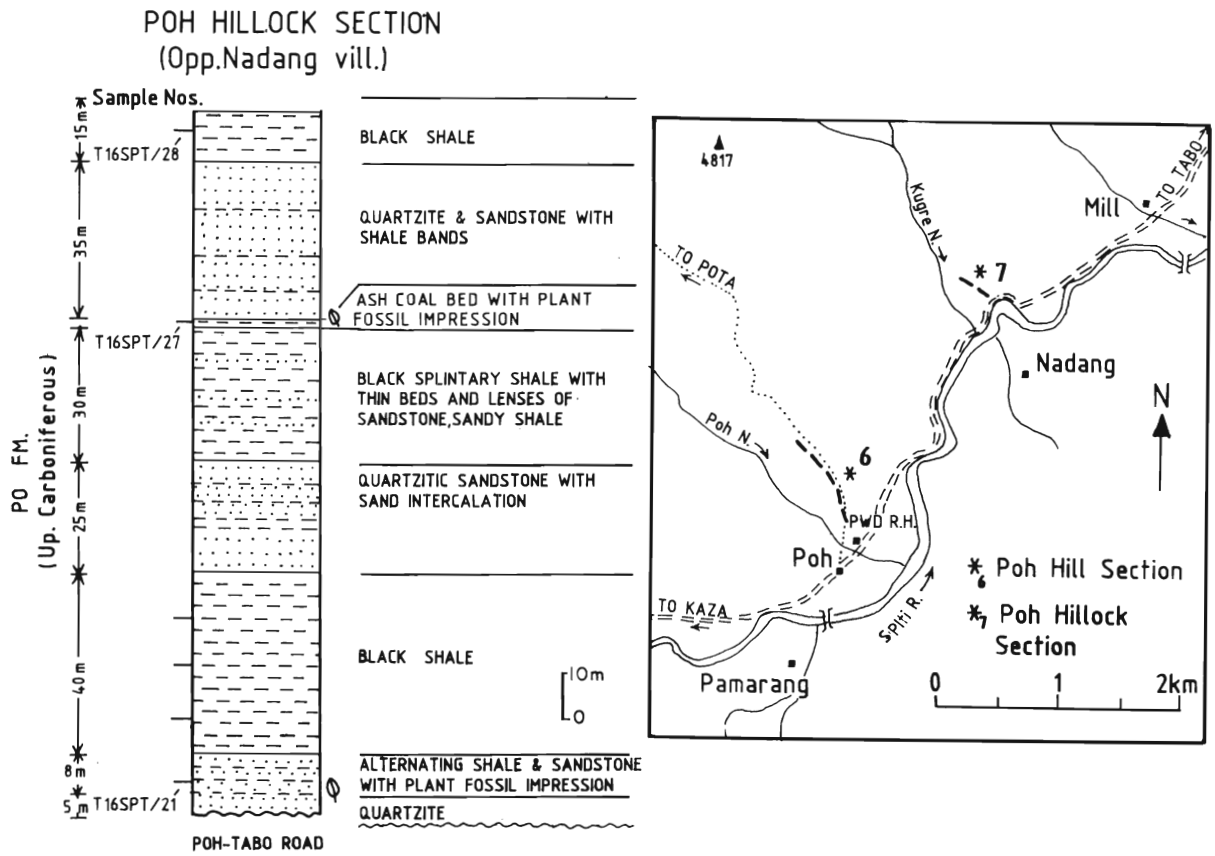


Fig. 3f. Poh Hillock Section, opposite Nadang Village, about 2.5 km from P.W.D. Rest House at Poh towards Tabo Village.

Poh Hillock Section

This section is located at about 2 km from P.W.D. Rest House at Poh towards Tabo, opposite Nadang Village (Plate I, fig. 4; location shown in fig. 3f). Here also only the Carboniferous rocks represented by Po Formation were studied (fig. 3f). Inspite of our efforts, no palynofossils could be recovered from this section, although a palyno-assemblage of Carboniferous age (Table 7) was recovered earlier by Khanna and Tiwari (1983). However, a few plant fossil impressions and bryozoans were encountered in the field.

Remarks : Palynoassemblage recovered earlier by one of the authors (RST) indicated an Early Carboniferous age to the upper stratigraphic level of the Po Formation (Khanna & Tiwari, 1983). This section has also yielded plant fossils from the levels of the Po Formation exposed just on the road. The fauna represented by bryozoans is poor.

Guling Section

The Guling Section is a classic section showing the continuous succession from Permian to Triassic (fig. 3 g). In this section the Permian sequence is represented mostly by Gechang and Gungri formations. The Ganmachidam Formation is, however, very thin. The Triassic sequence is quite thick, represented by limestones and interbedded thin shales. A close sampling was made and 35 samples were collected, but none of these samples yielded palynofossils. The Gechang Formation yielded spiriferids and productids. The limestone-shale unit of the Lilang Group has yielded ammonoids and bivalves.

DISCUSSION AND CONCLUSIONS

1. Lithostratigraphically, the Carboniferous and the Permian successions are represented by Kanawar Group and Kuling Group, respectively. The Kanawar Group is divisible into the basal Lipak Formation and the upper Po Formation. The Kuling Group is divisible into three formations. These, in ascending order, are : Ganmachidam Formation (earlier placed under the Carboniferous), Gechang Formation and Gungri Formation. The status of Kuling is raised from Formation to the level of Group, and those of the Gechang and Gungri from Member to the level of Formation.

2. The presently carried out palynological investigations from the Spiti Valley adds to our knowledge of palynofossils in the Tethyan sequence of the Himalaya. Prior to this record, important data on palynology from

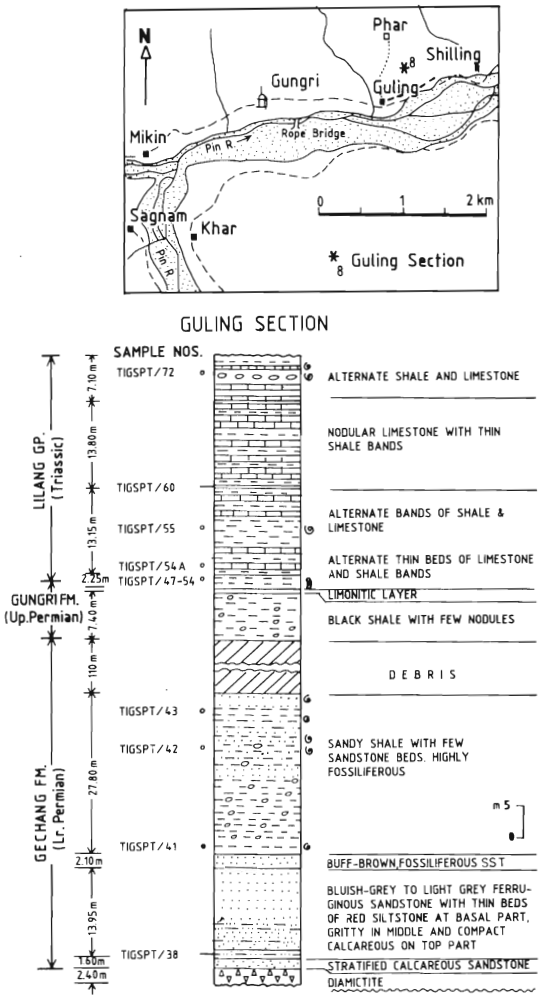


Fig. 3g. Guling Section in Pin Valley.

two areas of the same basinal region are known -- 1. Malla Johar area (Tiwari *et al.*, 1984) and, 2. Niti area (Tiwari *et al.*, 1995). In these areas, the Permian and Triassic palynofloras are now known from five sections. However, only in three sections superimposed successional sequences of Permian and Triassic have yielded spores and pollen.

In Niti area, the Upper Permian Kuling Shale Formation of Hotigad Shal-Shal Section yielded a *Striatopodocarpites-Crescentipollenites* (SC) complex, additionally having *Densipollenites, Faunipollenites, Rhizomaspora, Satsangisaccites, Krempipollenites* and *Arcuatipollenites*. In the same section, about 2.25 m above the topmost sample which yielded Permian palynoflora listed above, the Rambakot Member of Lower Triassic Shal-Shal Formation revealed the presence of *Striatopodocarpites-Krempipollenites* (SK) complex having *Densoisporites, Lundbladispora, Kraeuselisporites, Playfordiaspora, Goubinispora, Arcuatipollenites*, cf. *Chordasporites*. This makes a remarkable succession of Upper Permian - Lower Triassic palynofloras in one individual section. The SK palynozone (*Striatopodocarpites- Krempipollenites* palynozone) has been located just below the *Ophiceras* bed in the Niti area.

In Malla Johar area, another Permian-Triassic palyno-succession has been tagged in the Upper Permian Kuling Shale Formation and the Lower Triassic Kalapani Limestone Formation of Summa- Sanchamala Section. However, in the latter the preservation of palynomorphs is not satisfactory to make critical assessment, yet the presence of *Densoisporites* and *Alisporites* is significant. The Kuling Shale palynoflora comprises SC palynozone (i.e., *Striatopodocarpites-Crescentipollenites* palynozone) hence it matches with the flora of Kuling Shale in Niti area.

In the presently studied Permian-Triassic sequence of Spiti Valley, particularly in Lingti Hill Section, the Upper Permian Gungri Formation (which is supposed to be equivalent to Kuling Shale of other areas) the SC palynozone has been identified. Beside diversified striate bisaccate pollen, the genera *Densipollenites* and *Lundbladispora* are also recorded in this zone indicating the youngest aspect of the Late Permian age. In the same section the basal part of the Lilang Group exhibits the SK palynozone, having additionally *Verrucosisporites, Arcuatipollenites, Kraeuselisporites, Lundbladispora*, and the striate bisaccate components being less diversified, indicating an Early Triassic age.

Further, in Spiti Valley, the SC palynozone has been identified in the Late Permian Gungri Formation exposed in Ganmachidam Hill Section. Significantly, an additional form - *Kamthisaccites*, has also been recorded.

From the above brief analysis it has become clear that the palynozone characteristic of the uppermost Upper Permian is identifiable in the Kuling Shale Formation and the Gungri Formation. The definite Lower Triassic palynozone has been recognized in the Rambakot Member of Shal-Shal Formation and also in the basal part of the Lilang Group.

The Permo-Triassic palynological change-over is very evident in the Niti area, i.e. in Kuling Shale Formation to Shal-Shal Formation. The similar pattern is seen in Spiti Valley, i.e., from Gungri Formation to Lilang Group. The Lingti Road and Lingti Hill sections have yielded Early Triassic elements, viz., *Lundbladispora, Kraeuselisporites, Arcuatipollenites Alisporites, Chordasporites*. The affinity of *Lundbladispora, Densoisporites* and *Kraeuselisporites*, specially their first appearance, confirms the proximity of Raniganj-Panchet Passage Bed (i.e., Permian/Triassic Passage Bed) in the Peninsular India. However, in Spiti its definite Triassic affinity is

Table 6 : Lingti Road Section

Horizon	Group/ Formation	Productive Samples	Spore-Pollen	Taphonomic Observations	Fauna
Lower Triassic	Lilang Group	T17SPT/101	*Faunipollenites* sp. *F. varius* *Striatopodocarpites* sp.	Light yellow brown, well preserved exine characters distinct, intact	—
Upper Permian	Gungri Formation	*T17SPT/89, 92	—	—	*Neospirifer* sp. *Mourlonia* sp. *Etheripecten* sp. *Cyclolobus* sp. *Xenapsis* sp.
Lower Permian	Gechang Formation	T17 SPT/86, 87,132,133, 135 *T17SPT/84	*Faunipollenites perexiguus* *Striatopodocarpites* sp. *Densipollenites diffusus* *Faunipollenites* sp. *Striatopodocarpites decorus* *Crescentipollenites* sp. *Vesicaspora* sp. *Verrucosisporites* sp.	Dark brown, exine characters indistinct, ill preserved, smoothered and some grains are broken	*Neospirifer* sp. *Linoproductus* sp. *Peruvispira* sp.

* - Samples yielded fauna

supported by the cephalopods present in those sediments which have yielded the palynomorphs. Thus, the general trend of palynofloral change in Spiti Valley, from Permian to Triassic, indicated by SC palynozone to SK palynozone, respectively, is similar to that of the non-marine sequences (Tiwari & Singh, 1986; Tiwari & Vijaya, 1994) of the Peninsular India. The tagging of marine and non-marine data through common factor of palynofossils at the P/Tr boundary strengthens the potential of palynozonation in chrono-stratigraphic determinations.

3. The impact of taphonomic factors on the palynofossils has been revealed by various states of preservation of exine. Well preserved spores and pollen from Carboniferous assemblage are dark brown to black in colour. The specimens are corroded but with intact exinal characters. The Lower Permian palynomophs are dark brown having indistinct exine characters, ill-preserved and broken. In the Upper Permian assemblage, the spores and pollen are generally dark brown with distinct exine structures. Light yellow forms are also present. It is significant to note that specimens are mostly intact, and not disintegrated. Few forms glassy in appearance are also observed. The Upper Permian palynoflora is fairly rich and diversified.

The Lower Triassic assemblage is poorly preserved and impoverished in forms.

The striking resemblance between the Permian assemblages of this part of Tethyan sequence and the precisely marked palynozones of the Peninsular India strengthens the earlier opinion (Tiwari & Vijaya, 1988) that the *Glossopteris* flora had extended onto the northern margin of the Peninsula upto the Tethys shore. The population of this flora grew along the sea and probably inhabitated the islands as well. However, some influence of northern elements during Early Triassic is indicated by the presence of few characteristic spore-pollen taxa (*Kraeuselisporites-Klausipollenites* complex).

4. The lithological characteristics, the faunal content and the palynological assemblage further decipher the nature of change-over at P/Tr boundary.

Lithologically, a thin ferruginous layer is observed in between the black shale of Gungri Formation and the limestone- shale unit of the Lilang Group at Mandaksa, Guling and Lingti road sections. The ferruginous layer is 4-6 cm in Mandaksa Section, 5-8 cm in Lingti Road Section (Plate I, fig. 8) and 3-5 cm in Guling Section. This marker layer, however, could not be observed in Poh, Lingti Hill and Ganmachidam sections, possibly because of erosional topography, which otherwise should be present there also. This ferruginous layer is limonitic in nature.

Table 7 : Poh Hillock Section

Horizon	Formation	Productive Samples	Spore-Pollen	Taphonomic Observations	Fauna
Upper Carboniferous	Po Formation	vide Khanna & Tiwari, 1983	*Valatisporites* sp. *Dibolisporites* sp. *Retispora* sp. *Corbulispora* sp. *Hymenozonotriletes* sp.	Dark black, exine characters not distinct, specimens corroded but intact	Productus sp. *Dielasma* sp. Bryozoans

Bhandari *et al.* (1992) have shown positive Iridium anomaly in this limonitic layer, and suggested it as a geochemical event marker for P/Tr boundary. This appears to be a global phenonmenon, as similar layer was observed in Guryual Ravine in Kashmir Valley by two of the present authors (TS and RST). Now, the Chinese group has found a clay bed near the Permian-Triassic boundary. Wang Cheng-yuan (1994) has marked this clay bed as the Evento-stratigraphic Boundary in Zhongxin Dadui section in Zhejiang Province.

The limonitic layer may also represent a hiatus, probably a break in sedimentation or subaerial weathering, and thus it may not be taken as true P/Tr boundary. Bhargava (1987), however, considers the Palaeozoic-Mesozoic boundary in the Spiti Basin to be characterised by continuous sedimentation, though a sudden change in fauna is manifested. This limonitic layer is, therefore, suggested to represent the Evento-stratigraphic boundary in the Spiti Valley, which may here also be very close to the P/Tr boundary as shown by Wang Cheng-Yuan (1994) is Zhejiang Province of China.

As far as the faunal contents, Bhatt *et al.* (1980) have shown three layers of ammonoid-bearing black shale in the Gungri Formation, one each at 1.30m, 3.0m and 8.13m, below the Triassic carbonate sequence. The ammonoids, which have the dominance of *Cyclolobus walkeri*, have been dated as representing Djulfian Stage. The black shale has also yielded brachiopods. The last occurrence of brachiopods in this sequence is recorded at a level about 2.85 m below the carbonate sequence (Shanker *et al.*, 1993).

The limestone-shale unit of the Lilang Group, referred to as the *Otoceras-Ophiceras* bed, on the other hand, has yielded cephalopods (*Otoceras*, *Ophiceras*, *Glyptophiceras*, etc.), bivalves (mainly *Claraia*), and other micro - fauna (conodonts, ostracodes, foraminifera). The fauna suggests that the Triassic strata have a complete sequence starting from Scythian (Bhatt & Joshi, 1981b; Bhatt & Arora, 1984; Bhargava & Gadhoke, 1988).

It is, thus, clear that although the Triassic carbonate sequence is fossiliferous almost just at the base, the top 1.30 m layer of Gungri Formation is unfossiliferous. Now it becomes important to look for the age of this 1.30 m unfossiliferous sequence to mark the exact datum line. Does this level correspond to Dorashamian/Changxingian to make the complete succession from Djulfian Stage of Permian to Griesbachian Stage of Triassic? This is more significant in view of presence of the ferruginous layer in between the black shale of Gungri Formation and the overlying limestone-shale unit of the Lilang Group.

Palynologically, the trend of palynofloral change from Permian to Triassic is closely comparable to the Peninsular India.

In the international perspective, the scenario of demarcation of P/Tr boundary is changing fast. Recently, Yin Hong-Fu (1994) reassessed the faunal changes at P/Tr boundary while proposing the most perfect boundary section in South China. He suggested a conodont species *Hindeodus parvus* as the index fossil for basal Triassic, and the base of the *H. parvus* zone as the Erathem boundary. He further suggested *Otoceras* as a potential index fossil but it needs further biostratigraphic and phylogenetic researches at species level. It is, thus, evident that in view of latest data an intensive analysis is needed in case of P/Tr boundary in the Spiti Valley.

It is now recommended here that the Spiti Valley be considered a Candidate Point for the International P/Tr Boundary Stratotype Section, in view of the presence of ferruginous layer and the FAD of *Lundbladispora*, *Densoisporites* and *Arcuatipollenites*. The other such recognised candidates by the International Stratigraphical Commission are : i) Meishan Section at Changxing in Zheijiang, ii) Shangshi Section at Guangyan in Sichuan, iii) Xishan Section at Selong in Tibet, and iv) Guryual Ravine Section at Kashmir in India.

ACKNOWLEDGEMENTS

This paper forms a part of the Collaborative Research Project between the Wadia Institute of Himalayan Geology and the Birbal Sahni Institute of Palaeobotany. These Institutions provided necessary facilities and extended full cooperation to the authors during the course of this work.

One of the authors (TS) is grateful to Dr. O.N. Bhargava for introducing to the area and guiding to select crucial stratigraphic sections and for purposeful discussions on the subject matter. The author (TS) is also grateful to Dr. Ravi Shanker, Prof. I.B. Singh and Dr. U.K. Bassi for fruitful discussions pertaining to geological set-up of the Spiti Valley.

REFERENCES

Bagati, T.N. 1990. Lithostratigraphy and facies variation in the Spiti Basin (Tethys), Himachal Pradesh, India. *J. Him. Geol.*, **1** : 35 - 47.

Bhandari, N., Shukla, P.N. and Azmi, R.J. 1992. Positive Iridium Anomaly at the Permo-Triassic Boundary, Spiti, India. *Geophy. Resear. Lett.*, **19** (15) : 1531 - 1534.

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

Bhargava, O.N. and Bassi, U.K. 1988. Trace fossils from the Palaeozoic - Mesozoic sequence of Spiti - Kinnaur (Himachal Himalaya) with comments on palaeoenvironmental control on their frequency. *J. Geol. Soc. India*, **32** (3) : 227 - 238.

Bhargava, O.N. and Gadhoke, S.K. 1988. Triassic microfauna of the Lilang Group with special reference to Scythian-Anisian Conodonts, Spiti Valley, Himachal Himalaya. *J. Geol. Soc. India*, **32** (6) : 494 - 505.

Bhargava, O.N., Srivastava, R.N. and Gadhoke, S.K. 1985a. *Zoophycos* from Permian Kuling Formation, Himachal Himalaya, India. *J. Geol. Soc. India*, **26** (2) : 137 - 140.

Bhargava, O.N., Srivastava, R.N. and Gadhoke, S.K. 1985b. *Eurydesma* from the Kuling Formation, Spiti Valley, H.P., *J. Palaeont. Soc. India*, **30** : 57 - 58.

Bhargava, O.N., Srivastava, R.N. and Gadhoke, S.K. 1991. Late Proterozoic-Palaeozoic Spiti sedimentary basin. In : S.K. Tandon, C.C. Pant and S.M. Casshyap (Eds.) *Sedimentary Basins of India : Tectonic Context*. *Gyanodaya Prakashan*, Nainital : 236 - 260.

Bhatt, D.K. and Arora, R.K. 1984. *Otoceras* Bed of Himalaya and Permian-Triassic Boundary - Assessment and elucidation with conodont data. *J. Geol. Soc. India*, **25** (11) : 720 - 727.

Bhatt, D.K., Fuchs, G., Prashara, K.C., Krystyn, L., Arora, R.K. and Golebiowski, R. 1980. Additional ammonoid layers in the Upper Permian sequence of Spiti. *Bull. Indian Geol. Ass.*, **13** (1) : 57 - 61.

Bhatt, D.K. and Joshi, V.K. 1978a. Early Lower Triassic conodonts from Spiti River section, *Curr. Sci.*, **47** (4) : 118 - 120.

Bhatt, D.K. and Joshi, V.K. 1978b. A record of foraminifera from the Lower Triassic strata of Spiti. *Curr. Sci.*, **47** (10) : 346.

Bhatt, D.K. and Joshi, V.K. 1981a. Artinskian (Lower Permian) in Spiti, Tethys Himalaya. *Rec. Geol. Surv. India*, **112** (8) : 45 - 50.

Bhatt, D.K. and Joshi, V.K. 1981b. A note on the occurrence of *Glyptophiceras* Spath from Spiti, with preliminary observations on the fauna of *Otoceras-Ophiceras* beds. *Rec. Geol. Surv. India*, **112** (8) : 51 - 54.

Bhatt, D.K., Joshi, V.K. and Arora, R.K. 1981a. Conodont of *Otoceras* Bed of Spiti. *J. Palaeont. Soc. India*, **25** : 130-134.

Bhatt, D.K., Joshi, V.K. and Arora, R.K. 1981b. *Neospathodus praekummelli* - a new species of conodont from Lower Triassic of Spiti. *J. Geol. Soc. India*, **22** (9) : 444 - 447.

Diener, C. 1899. Anthracolithic fossils of Kashmir and Spiti. *Palaeont. Indica*, Ser. 15, **5** (1), pt. 2 : 1 - 95.

Diener, C. 1909. Lower Triassic Cephalopoda from Spiti, Malla Johar and Byans. *Palaeont. Indica*, Ser. 15, **6** (1) : 1 - 186.

Diener, C. 1912. The Trias of the Himalaya. *Mem. Geol. Surv. India*, **36** (4) : 202 - 360.

Diener, C. 1915. The Anthracolithic faunae of Kashmir, Kanaur and Spiti. *Palaeont. Indica*. N.S., **5** (2) : 1 - 135.

Goel, R.K. 1977. Triassic conodonts from Spiti (H.P.), India. *J. Palaeont.*, **51** : 1085 - 1103.

Goel, R.K. 1982. Triassic conodont sequence in Spiti. *Geol. Surv. India, Misc. Publ.*, **41** (2) : 205 - 213.

Gothan, W. and Sahni, B. 1937. Fossil plants from the Po-Series of Spiti, NW Himalaya. *Rec.Geol.Surv.India*,**72** (2) : 195-206.

Griesbach, C.L. 1889. Geological notes - the sequence of formations in Spiti. *Rec. Geol. Surv. India*, **22** : 149 - 208.

Hayden, H.H. 1904. The geology of Spiti with parts of Bashahr and Rupshu. *Mem. Geol. Surv. India*, **36** (1) : 1 - 124.

Hoeg, O.A., Bose, M.N. and Shukla, B.N. 1955. Some fossil plants from the Po Series of Spiti (N.W. Himalaya). *Palaeobotanist*, **9** : 10 - 13.

Kanwar, S.S. and Ahluwalia, A.D. 1979. Lithostratigraphy of Upper Palaeozoic Tethyan Sequence in Chandra Valley near Bara Lacha La, District Lahul and Spiti, Himachal Pradesh, India. In : V.J. Gupta (Ed.) *Contributions to the Himalayan Geology*. **1**. Upper Palaeozoic of the Himalaya. Hindustan Publishers, Delhi : 147 - 153.

Khanna, A.K. and Tiwari, R.S. 1983. Lower Carboniferous miospore assemblage from Po Formation, Tethys Himalaya and its stratigraphic significance. *J. Palaeont. Soc. India*, **28** : 95 - 101.

Lydekker, R. 1883. The geology of Kashmir and Chamba territories and British District of Khagan. *Mem. geol. Surv. India*, **22** : 1 - 344.

Oldham, R.D. 1888. The geology of Northwest Himalaya. *Rec. geol. Surv. India*, **21** (4) : 149 - 157.

Ranga Rao, A., Dhar, C.L., Jokhan Ram, and Shah, S.K. 1984. Contribution to the stratigraphy of Spiti. *Him. Geol.*, **12** : 98 - 113.

Shanker, R., Bhargava, O.N., Bassi, U.K., Mishra, R.S., Chopra, S., Singh, I.B. and Singh, Trilochan 1993. Biostratigraphic controversy in the Himalaya : an evaluation in Lahaul-Spiti, Himachal Pradesh. *Indian Minerals*, **47** (4) : 263 - 286.

Srikantia, S.V. 1981. The lithostratigraphy, sedimentation and structure of Proterozoic-Phanerozoic formations of Spiti Basin in the Higher Himalaya of Himachal Pradesh, India. In: A.K.Sinha (Ed.) *Contemporary Geoscientific Researches in the Himalaya*. Mahendra Pal Singh Publ., Dehradun, India : 31-48.

Srikantia, S.V., Bhargava, O.N. and Kapoor, H.M. 1978. A note on the occurrence of *Eurydesma* and *Deltopecten* assemblage from the Kuling Formation (Permian), Baralacha Ban Area, Lahaul Valley, Himachal Pradesh. *J. Geol. Soc. India*, **19** (2) : 73 - 78.

Stoliczka, F. 1865. Geological section across the Himalayan Mountain from Wangtoo Bridge on the river Sutlej to Sungdo on the Indus; with an account of formations of Spiti accompanied by revision of all known fossils from that district. *Mem.Geol. Surv. India*, **5** : 1 - 154.

Tewari, A.P. 1959. Two new species of *Bellerophon* from the Permo-Carboniferous of Spiti Himalaya. *Rec. Geol. Surv. India*, **89** (2) : 435 - 440.

Tiwari, R.S. 1974. Inter-relationships of palynofloras in the Barakar Stage (Lower Gondwana), India. *Geophytology* **4** (2) : 111 - 129.

Tiwari, R.S. and Ram-Awatar 1989. *Sporae dispersae* and correlation of Gondwana sediments in Johilla Coalfield, Son Valley Graben, Madhya Pradesh. *Palaeobotanist*, **37** (1) : 94 - 114.

Tiwari, R.S. and Singh, Vijaya 1986. Palynological evidences for Permo-Triassic boundary in Raniganj Coalfield, Damodar Basin, India. *Bull. Geol. Min. Metall. Soc. India*, **54** : 256-264.

Tiwari, R.S., Singh, Vijaya, Kumar, S. and Singh, I.B. 1984. Palynological studies of the Tethyan sequence in Malla Johar area, Kumaon Himalaya, India. *Palaeobotanist*, **32** (3) : 341 - 367.

Tiwari, R.S. and Vijaya 1988. Reflection on relationship of Tethyan palynoflora. *Palaeobotanist*, **36** : 339 - 353.

Tiwari, R.S. and Vijaya 1991. Permo-Triassic boundary on the Indian Peninsula. In: Sweet *et al.* (eds.) - *Permo-Triassic Events in the Eastern Tethys*, Cambridge Univ. Press : 37-45.

Tiwari, R.S., Vijaya, Mamgain, V.D. and Misra, R.S. 1995. Palynological studies on Late Palaeozoic-Mesozoic Tethyan sequence of Himalayas in Niti area, Uttar Pradesh, India. *Rev. Palaeobot. Palynol.* (in press).

Wang Cheng-yuan 1994. A conodont based high resolution event-to-stratigraphy and biostratigraphy for the Permian-Triassic boundaries in South China. *Palaeoworld* **4** : 234-248.

Waterhouse, J.B. 1986. The Permian Gungri Formation (=Kuling or Productus Shale) and a new Sandstone Member in South Zanskar. *Bull. Indian Geol. Ass.*, **18** (2) : 67 - 78.

Yin, Hong-fu 1994. Re-assessment of the Index Fossils at the Palaeozoic-Mesozoic Boundary. *Palaeoworld* **4** : 153 - 171.

EXPLANATION OF PLATES

Plate I

1. Tethyan Sequence as viewed from the Takche Plain.
2. Ganmachidam Hill showing alternate sequence of shale and sandstone of the Po Formation (Carboniferous) in the lower part. The middle part represents the Permian sequence. The peak is represenetds by the Triassic Limestone of the Lilang Group.
3. Lingti Hill showing Permian - Triassic succession measured during the present study. As viewed from the Irrigation and Public Health hut at Lingti Camp.
4. Poh Hillock Section, opposite Nadang Village showing alternate sequence of shale and sandstone of the Po Formation. View from the PWD Rest House at Poh.
5. Pinch and Swallow structure in the Po Formation observed in Poh Hill Section.
6. Star Fish in the siltstone recovered from the Po Formation exposed in Ganmachidam Hill Section.
7. The ferruginous layer in between the black shale of the Gungri Formation and limestone-shale unit of the Lilang Group, in Lingti Road Section.
8. Calcareous concretionary nodules in the black shale of the Gungri Formation in the Lingti Road Section.

Plate II

1-18: Representative palynotaxa of the Gechang Formation from Mandaksa Nala Section, Lower Permian (ca x 500)

1, 10, 15. *Striatopodocarpites* sp. BSIP Slide Nos. 11370, 11365, 11366

2. *Cordaitina* sp. BSIP Sl. No. 11364
3. cf. *Indotriradites barakarensis* BSIP Sl. No. 11388
4. *Rhizomaspora indica* BSIP Sl. No. 11362
5. *Cuneatisporites* sp. BSIP Sl. No. 11367

6, 13. *Scheuringipollenites barakarensis* BSIP Sl. No. 11369

7. *Microfoveolatispora* sp. BSIP Sl. No. 11363
8. *Striatites* sp. BSIP Sl. No. 11367
9. *Microbaculispora* sp. BSIP Sl. No. 11376
11. *Crescentipollenites* sp. BSIP Sl. No. 11368
12. *Vesicaspora* sp. BSIP Sl. No. 11367
14. cf. *Alisporites* sp. BSIP Sl. No. 11360
16. cf. *?Corisaccites* sp. Sl. No. 11361
17. *Jayantisporites pseudozonatus* BSIP Sl. No. 11363
18. *Densipollenites indicus* BSIP Sl. No. 11367

Plate III

1- 13 : Representative palynotaxa of the Gungri Formation from Ganmachidam Hill Section (ca x 500)

1. *Plicatipollenites indicus* BSIP SL. No. 11371
2. *Faunipollenites* sp. BSIP Sl. No. 11386
3. *Striatites* sp. BSIP SL. No. 11371
4. *Crescentipollenites fuscus* BSIP Sl. No. 11378
5. *Krempipollenites* sp. BSIP Sl. No. 11371

6,7. *Crescentipollenites* sp. BSIP Sl. Nos. 11372, 11371

8. *Kamthisaccites* sp. BSIP Sl. No. 11375

9,11. *Faunipollenites varius* BSIP Sl. Nos. 11377, 11371

10. *Striatopodocarpites decorus* BSIP Sl. No. 11375

12. cf. *Densipollenites magnicorpus* BSIP Sl. No. 11375
13. cf. *Densoisporites* sp. BSIP Sl. No. 11378

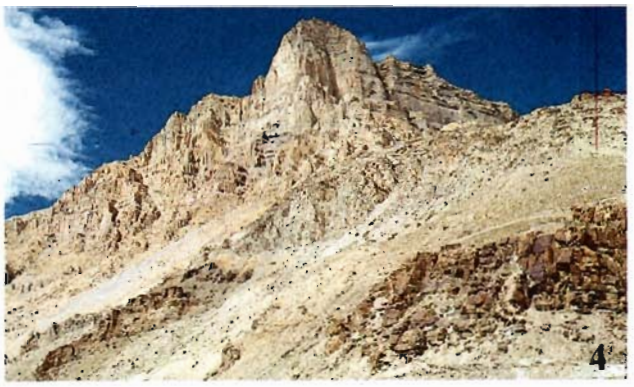
Plate IV

1 - 14 : Representative palynotaxa of the Gungri Formation and Lilang Group from Lingti Hill & Lingti Road Section (ca x 500)

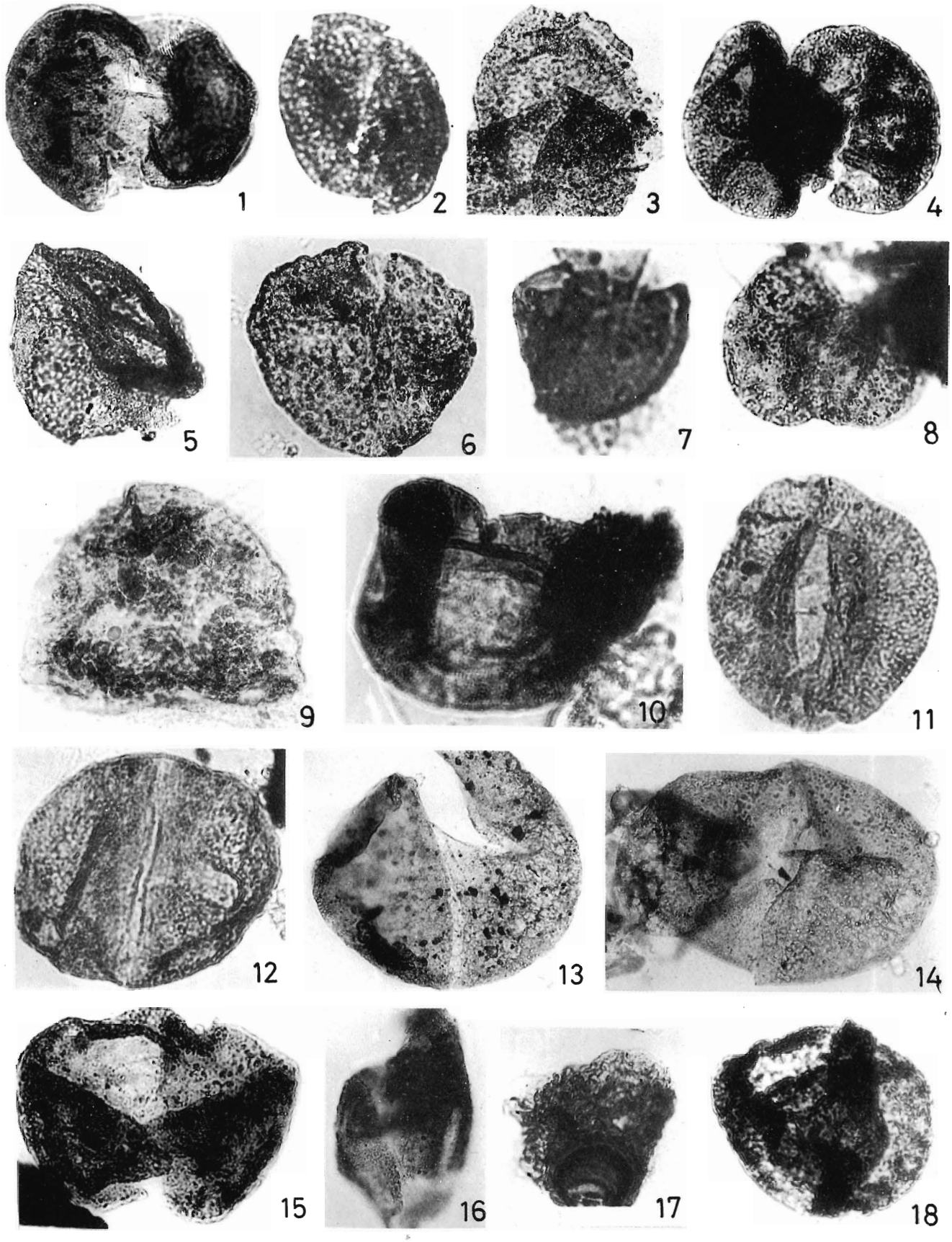
1. cf. *Arcuatipollenites ovatus* BSIP Sl. No. 11384
2. *Densipollenites indicus* BSIP Sl. No. 11379

3,12. *Faunipollenites varius* BSIP Sl. Nos. 11388, 11389

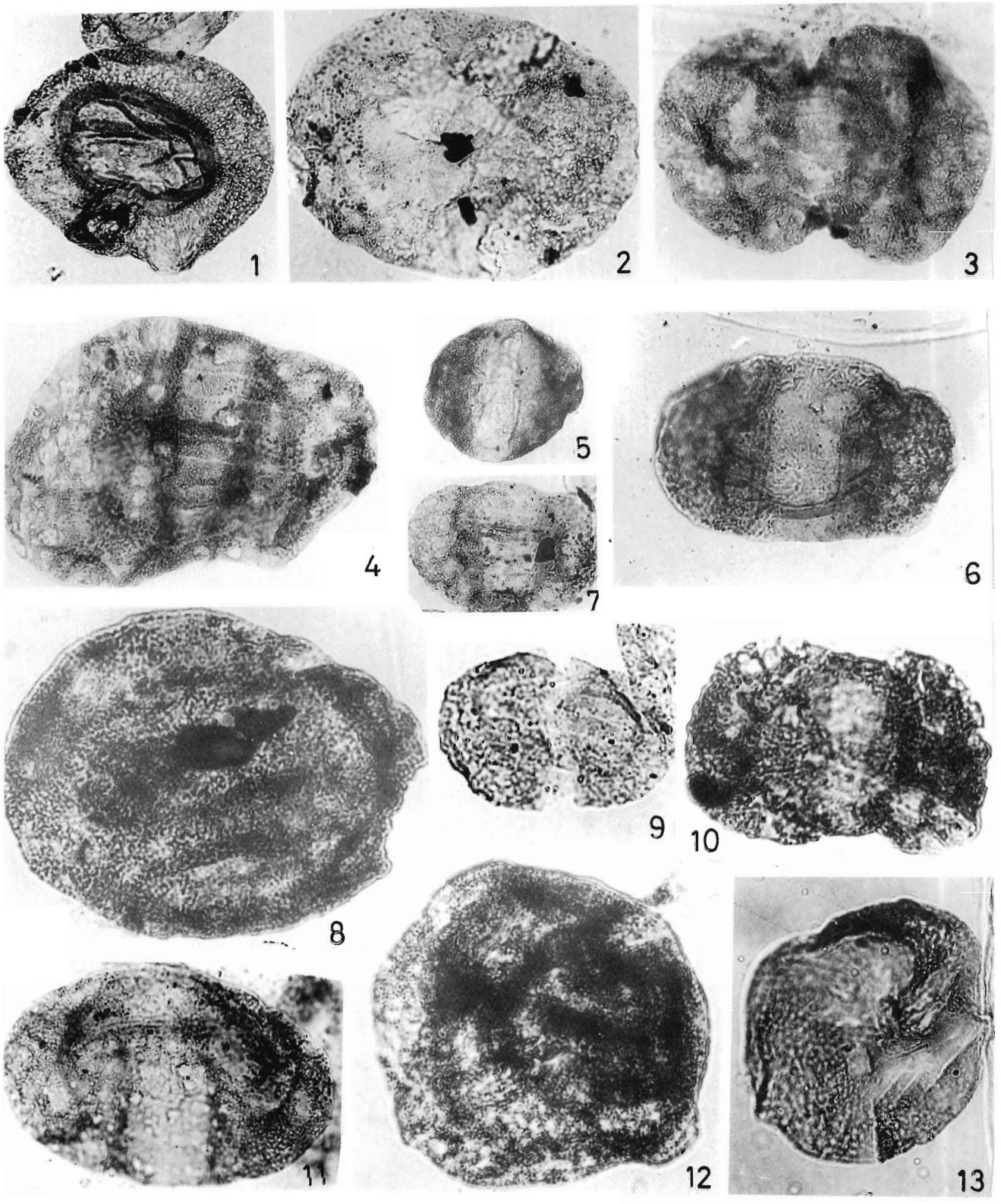
4. *Parasaccites korbaensis* BSIP Sl. No. 11379
5. *Lundbladispora microconata* BSIP Sl. No. 11380
6. cf. *Converrucosisporites* sp. BSIP Sl. No. 11387
7. cf. *Striatopodocarpites ovatus* BSIP Sl. No. 11379
8. cf. *Densoisporites* sp. BSIP Sl. No. 11380
10. *Striatites* sp. BSIP Sl. No. 11390
9. *Simeonospora* sp. BSIP Sl. No. 11385
11. *Kraeuselisporites* sp. BSIP Sl. No. 11381
13. *Crescentipollenites fuscus* BSIP Sl. No. 11374
14. *Osmundacidites senectus* BSIP Sl. No. 11382

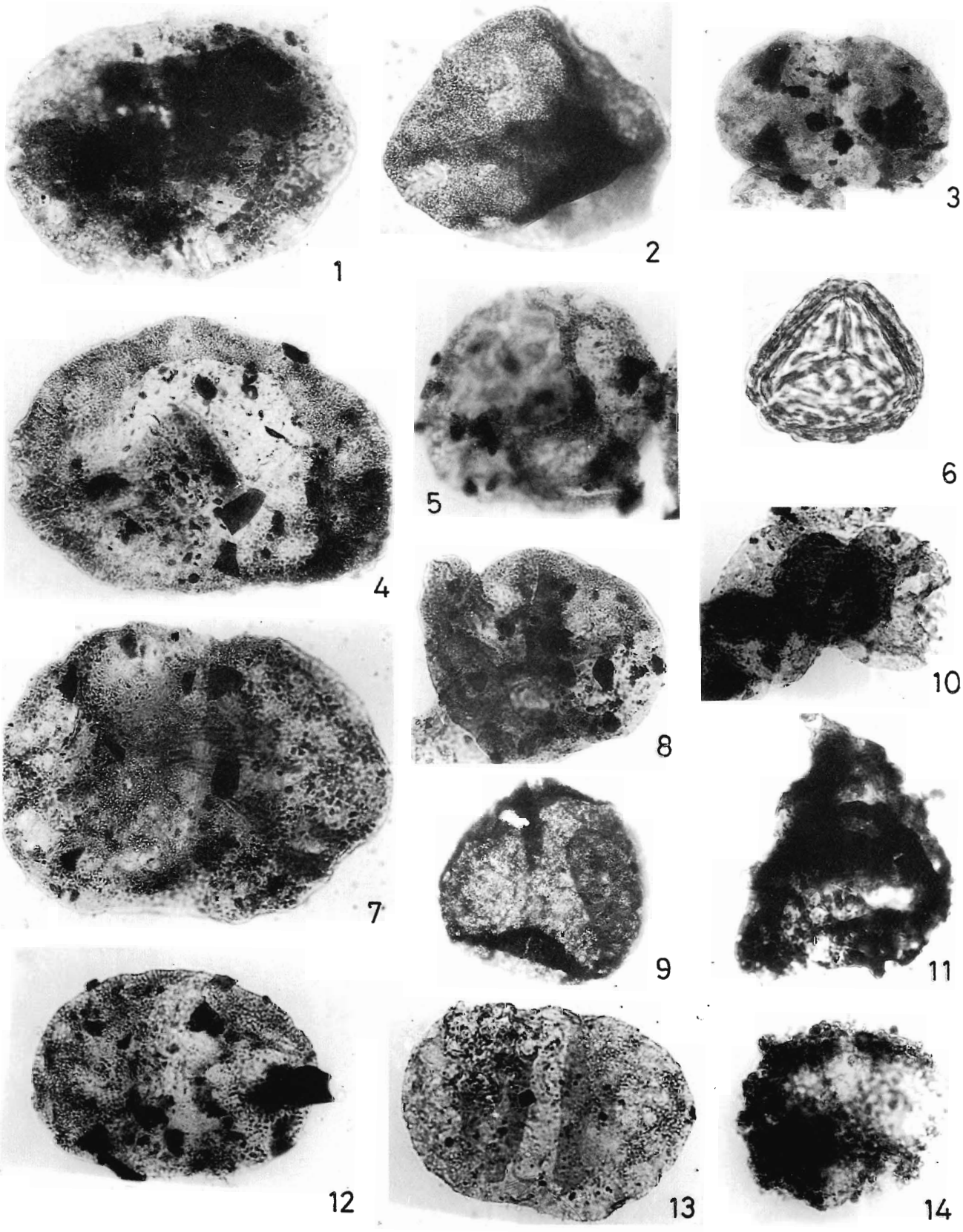


SINGH, TIWARI, VIJAYA AND RAM-AWATAR



SINGH, TIWARI, VIJAYA AND RAM-AWATAR


1
2
3
4
5
6
7
8
9
10
11
12
13


1
2
3
4
5
6
7
8
9
10
11
12
13
14