PALYNOLOGY IN HIMALAYAN STRATIGRAPHY

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ABSTRACT

The paper identifies some of the vexed stratigraphical problems and complex areas in the Himalaya where palynological method could be beneficially applied. Lack of reliable stratigraphic controls has been a major handicap in the recognition and assignation of time-stratigraphic equivalence to many rock sequences in Himalaya. The scope and potentiality of palynology as an effective and reliable tool to help and resolve various types of age and correlation problems in the Complex Himalayan set up is discussed.

INTRODUCTION

AN analysis and synthesis of available data on the stratigraphy and structure of Himalaya clearly reveals that in spite of several regional and many detailed studies, the reconstruction of the geological history of this youngest, highest, and largest mountain system has remained more or less imperfect even today. This is due to the lithologic similarity and unfossiliferous rock sequences which are in apparent conformable or pseudo-conformable relationship. The problems are admittedly complex and controversial. Recent trends in the application of modern dating and biostratigraphic techniques indicate that many problems of age determination, correlation, and interpretation of structural complexities can be satisfactorily solved by palynological method.

Palynology may constitute one of the most promising as well as rewarding field of research in the elucidation of Himalayan stratigraphy. During the past two decades a large amount of basic data which has a potential application value to solve stratigraphic problems, has been collected. Palynological information in earlier years (fifties & early sixties) was mostly classical, the emphasis being laid on the taxonomic treatment of fossil spores and pollen grains from isolated grab samples. The Palaeozoic-Mesozoic rocks, particularly the coal-bearing strata from the Indian shield, received greater attention of Indian palynologists. Efforts made towards finding ages of some of the more important stratigraphic horizons of Lesser Himalaya like the Blainis, Infra-Krols and Krols by palynological method, though scanty, have yielded very encouraging results. Lately, the emphasis has shifted to analytical and interpretative investigations which have direct bearing on stratigraphy. The importance of this method in the exploration for oil naturally shifted the areas of palynological research to Tertiary sedimentary basins like Assam, Cambay, Cauvery and Punjab. However, the application of palynological method in the solution of complex stratigraphical problems in Himalaya still remain negligible and like earlier years confined to isolated grab samples whose precise stratigraphic positions are even not clear. Lack of sufficiently detailed investigations are likely to create more confusion than help to solve problems of stratigraphic reconstructions. To establish geologically credible time planes and correlative horizons, it is essential that detailed studies on as many stratigraphic sections as possible should be initiated.

The Himalayan orogenic belt runs for a strike length of over 2400 km and covers a width varying from 230 to 320 km. Five lithotectonic zones from south to north have been recognized. The southernmost or Zone-1 is the Sub-Himalayan belt consisting of Neogene and later deposits accumulated in a fore-deep, which have been folded, faulted and thrusted by movements which continue even today. The Lesser Himalaya, constituting Zone-2, is characterized by the so-called platform type of sediments. These are believed to be the northern continuation of the shield elements, overthrust by southwardly directed nappes and thrust sheets. The Higher Himalaya form the Zone-3 and represents a line of greatest uplift. It is also the principal metamorphic belt. The Tethys Himalaya marks the Zone-4, which is characterized by fossiliferous sediments from late Pre-Cambrian to Upper Cretaceous. Zone-5, or the Indus Suture Zone, consists of Cretaceous flysch sediments with basic and ultrabasic rocks, exotic blocks and associated Palaeogene molasse. It is also generally referred as the 'Ophiolite Zone' because of its typical rock assemblage comprising ophiolitic rocks of Cretaceous age.

The present paper is intended to focus attention on the importance and scope of palynological research in each of these lithotectonic zones. The lithostratigraphy of the rock sequences in different zones will be briefly discussed in order to plan future lines of research, especially with respect to the possibility of palynofossil recovery and enrichment. The sporadic reports of palynological finds from various horizons of Himalaya (Sah & Kar, 1972; Singh *et al.*, 1973; Srivastava & Venkataraman, 1975; Sah *et al.*, 1977) testify to a very promising and rewarding field and also is a clear pointer that serious attempts in this direction will help to resolve some of the stratigraphic differences and sharply contrasting models of structural reconstructions. The paucity of megafossils in general, together with a rarity of lithological markers, and frequency of lateral variations, leaves us with no option but to develop a method which could serve as an effective tool for resolving various types of age determination and correlation problems and environmental interpretations for a better understanding of the Himalayan stratigraphy. To make palynological method an effective stratigraphic tool it will, however, be necessary to initiate systematic and intensive studies on measured stratigraphic sections; develop perfect methods and techniques for separating organic entities from a variety of rock types, more often metamorphosed; establish microfloral assemblages, marker fossils, range zones; and develop precise understanding of environmental characteristics; classification methods, etc.

CRITICAL AREAS AND PROBLEMS

There are a number of complex problems and areas which appear to be promising and worthy of palynological investigations. A brief examination of some of the critical areas and debatable problems may help in the selection of some suggested lines of investigation.

1. Sub-Himalaya

The rock sequences of the Siwalik System, mostly characterized by lacustrinal and fluvial deposits, are developed all along the Sub-Himalayan belt. They are lithologically divided into Lower, Middle and Upper Siwalik formations. The estimated age of the Siwalik sequence ranges from Middle Miocene to Upper Pleistocene. Sahni and Mathur (1964) and recently Karunakaran and Ranga Rao (1976) have given a comprehensive review of the literature on the Siwalik Group. From these it becomes apparent that the classification, age and correlation of the Siwalik Group is still a debatable problem. Palynological records from this important stratal succession extending throughout the length of Himalaya, from Indus in the West to Mishmi Hills in the East, clearly indicate that application of palynological method might prove very rewarding in clarifying the Siwalik stratigraphy.

In a short paper on the palynology of the Lower and Middle Siwalik rocks of the Bhakra-Nangal area, Banerjee (1968) reported angiospermic pollen including those having affinity with Palmae together with pteridophytic spores. The identification of palm pollen, if authenticated, would tend to indicate a coastal environment of deposition. This would have an important palaeoenvironmental and palaeogeographic significance. The Middle Siwalik assemblage recorded by Lukose (1968) from Raxaul (Bihar) is characterized by gymnospermous pollen grains. Such a record has a significant bearing on the elevation attained by the Himalayan ranges of Bihar during Upper Miocene times. Recently, Nandi (1972, 1975) has recorded an Upper Siwalik microflora from near Mohand in Uttar Pradesh, and has also attempted to establish the palynostratigraphy of the Siwalik Group of Punjab.

Venkatachala (1972, 1977) has reported some characteristic genera obtained from the Lower, Middle and Upper Siwaliks. The Lower Siwaliks are represented by pteridophytic genera like *Cyathidites*, *Hymenophyllumsporites*, *Pteridacidites*, *Poly-*

podiaceoisporites, *Polypodiidites*, *Verrucatosporites*, *Verrucososporites*, *Laevigatosporites*, *Leptolepidites*, *Lycopodiumsporites*, *Cicatricosisporites*, *Osmundacidites*, *Rugulatisporites*, etc. Angiospermous genera include *Monoporopollenites*, *Cupuliferoidaepollenites*, *Cyrillaceapollenites*, *Betulaepollenites*, *Myrtaceidites*, *Caryapollenites*, *Alnipollenites*, etc. The gymnospermous genera like *Abiespollenites*, *Piceapollenites*, *Podocarpidites*, *Tsugaepollenites* indicate an elevation of at least 6,000 ft of the Middle Siwalik sediments. Palynofossils in the Upper Siwaliks are sporadic and represented by characteristic genera like *Cyathidites*, *Gleicheniidites*, *Pinuspollenites*, *Alnipollenites*, *Podocarpidites*, etc.

Based on vertebrate fauna and lithology, Pilgrim (1913) further subdivided the three broad divisions of the Siwalik System. For example, the Lower Siwalik has been divided into Kamlial and Chinji, the Middle into Nagri and Dhokpathan and the Upper into Tatrot, Pinjor and Boulder Conglomerate stages. The subdivision of the Siwalik formations into these stages cannot be recognized beyond a limited area as vertebrate fauna has been preserved only in this limited area. Palynological method may, therefore, be usefully applied in the zonation and correlation of the Siwalik sequence. The palaeoclimatic and palaeogeographical conditions at different stages of the Siwalik sedimentation can also be precisely interpreted with the help of palynological fossils.

In Jammu area, the Murree Formation overlies the Subathu sediments of Eocene age. The Dharamsala Formation in Himachal Pradesh is considered equivalent to the Murree Formation of Jammu area on the one hand and Kasauli and Dagshai formations of Simla Hills on the other. Earlier workers considered the Murree Formation together with the Kasauli and Dagshai formations to be fresh- to brackish-water deposits. According to a recent study by Raiverman and Raman (1971), the Subathu, Dagshai and Kasauli formations represent intertonguing amongst three distinct lithofacies which were deposited in marine to transitional environments. Recently, Ranga Rao (1971) has reported Eocene mammalian fauna from Kalakot zone in Jammu area. This zone forms the lower part of the Lower Murree which was previously considered to be Lower Miocene in age. Thus it appears that the stratigraphy of the Murrees/Dharamsalas, Dagshais and Kasaulis is still confusing with regard to both age and environment of deposition.

There is very little information available about palynological records from the Murrees (= Dharamsalas), Dagshais or Kasaulis of north-west Himalaya. Ghosh and Srivastava (1962) described some palynomorphs from the Dharamsala sediments (Upper Eocene-Lower Miocene) of Kangra District, and Venkatachala (1972) also listed the assemblages from Lower as well as Upper Dharamsalas. Mathur (1965) assigned a Middle to Upper Eocene age to the Subathu Formation on the basis of *Pediastrum*, *Botryococcus* and pollen, spores and hystrichosphaerids from Himachal Pradesh. Salujha *et al.* (1969) studied palynofossils from Simla Hills and suggested a Lower Eocene age for the formation. All these isolated and incomplete palynological records indicate that there is a good possibility of a precise palynostratigraphic zonation of the Palaeogene-Neogene sediments of Himalaya.

2. Lesser Himalaya

There is even greater confusion and controversy regarding the stratigraphy of the Lesser Himalaya because of the largely complex structural relationship of sequences and apparently unfossiliferous nature of the sediments. The reported occurrences of megascopic fossils are very few and far between, more or less confined to a few outcrops of the Permian, Jurassic and Cretaceous fauna from the Tal Formation of Garhwal. Palynological information is of a very limited stratigraphic value as it is based on a few isolated stratigraphic levels and random sampling. Concerted and systematic approach has not been attempted in the search for palynological remains in most of the sediments of Lesser Himalaya. The discovery of palynomorphs from the Jutogh (Sah *et al.*, 1977), Blaini (Srivastava & Venkataraman, 1975), Infra-Krols (Sah *et al.*, 1968), and Tals (Mehrotra *et al.*, 1976) indicate good prospects towards the discovery of more fossiliferous horizons with richer palynofossil assemblages. The recent finding of palynofossils from the Garu Formation (Marine Permian) of Arunachal Himalaya (Singh, unpublished thesis) is significant. This assemblage from the shale-sandstone sequences of Arunachal Pradesh has not only helped in ascribing a Lower Permian age to the Permian sediments but the close Indian Gondwana affinity of the fossils indicates possibility of significant palaeogeographic reconstructions.

The northern boundary of the Lesser Himalaya is delimited by the Main Central Thrust and southern by the Main Boundary Fault. A closer appraisal of the Lesser Himalayan stratigraphy is essential to identify prospective horizons which have greater possibility of yielding palynological remains. According to Jhingran *et al.* (1976), four principal lithotectonic units can be recognized in the Lesser Himalaya of Himachal, Garhwal and Kumaon. These are: Krol Nappe Unit, Simla Slate-Damta Unit, Shali-Deoban Unit, and Crystalline Klippen Unit.

Krol Nappe Unit — The rocks of the Krol belt extend from Simla in Himachal Pradesh to Naini Tal in Kumaun. Auden (1934, 1937) made important contributions to the geology of the Krol belt. Recently, Bhargava (1972) has given a reinterpretation of the Krol belt. The stratigraphic sequence of the Krol belt is given in Table 1 (Asterisk denotes lithologies with a fair/good chances of palynomorph recovery).

Organic remains have been reported from the Blaini, Infra-Krol, Krol and Tal formations, which clearly indicate that this thick unfossiliferous sequence, in fact, does contain palynofossils. Detailed palynological investigations may provide rich rewarding data. Srivastava and Venkataraman (1975) reported a rich assemblage of palynomorphs from the Blaini Formation of Himachal

TABLE 1 — LITHOSTRATIGRAPHIC SEQUENCE OF KROL BELT

Rock units		Principal lithology
Tal	Upper	White to pale green arkosic quartzite with intercalated pebbly sandstone, limestones, purple, red-*green micaceous *shales.
	Lower	Dark, often calcareous greywackes, *carbonaceous and micaceous shales and quartzites.
Krol limestone	E	Thick-banded, grey to creamy-white, microcrystalline limestones.
	D	White, soft sandstones and pockets of gypsum in limestone.
	C	Cliff forming limestones with secondary dolomitization, and cherty limestones.
	B	Thinly-bedded, *greenish or purple shales, containing thin layers of dolomitic and siliceous limestones.
	A	Alternating thin limestones and calcareous *shales, with thin bands or small concretions of black *cherts.
Krol sandstone		Badly bedded, orange coloured sandstones with small pockets of *siltstones.
Infra Krol		*Dark shales, slates and banded quartzite, with black *carbonaceous shales or slates at the top.
Blaini		Dark grey, brown, greenish to pinkish-microcrystalline limestones, and boulder bed, intercalated *siltstones, *shales and sometimes *claystones.
Nagthat		Sandstones, arkose, grits, quartzites, conglomerates, purple and *green clay slates and carbonaceous *phyllites.
Chandpur		Fine quartzites and *phyllites, massive quartzites together with green chloritic tuffs and tuffaceous slates in the upper part, occasional intercalations of *shaly layers.
Mandhali		Quartzites and *shales in lower part, followed by crystalline limestone or marble, gritty to conglomeratic quartzites passing into boulder beds, overlain by dark microcrystalline limestones.
Shali = Deoban Simla-Damta		Limestone with stromatolitic quartzite, *shales and slates, turbidites, greywackes, *siltstones.

Pradesh. The assemblage includes such characteristic palynofossils genera like *Reticulatisporites* sp., *Densosporites* sp., *Latosporites* sp., *Tripartites* sp., *Triquitrites* sp., *Maranhites* sp. etc., if proved authentic, undoubtedly indicates a Carboniferous age for the shales (B Member) of the Blaini Formation. Prasad and Bhatia (1975) recorded scalariform tracheids, some foraminifers, ostracods, algae and shell-fragments from the calcarenite unit of the lower Blaini tillites of Simla Hills which provide additional corroborative evidence in favour of a Permo-Carboniferous age for the Blainis. Sah *et al.* (1968), on reappraisal of the palynological assemblage recovered from the Infra-Krol shales of Bhowali (Naini Tal), assigned a Permo-Triassic age to the Infra-Krol shales, which is in conformity with other evidences. Similarly Tewari and Kumar (1967), and Sinha (1975) assigned a Jurassic-Cretaceous age to the Krol-Tal sequence on the basis of microfossils and nannofossils. Such a dating is also in close agreement with the lithostratigraphic setting of the area. However, the age controversy of the Krol-Tal sequence continues to remain so because of the fossil find of Kalia (1974) and supported by Valdiya (1975). Their contention of a Permian age for the Tal Formation and consequently Ordovician-Devonian for Krol — Infra-Krol sequence and Cambrian for the Blainis offers an altogether different stratigraphic reconstruction. If the latter view proves correct, it would imply that the entire Mesozoic period witnessed a non-depositional phase. What would be a reasonable palaeogeographic reconstruction model for the period? In a recent paper Mehrotra *et al.* (1977) have clearly brought out the complex stratigraphic set up in the area because of a number of thrust sheets. In their opinion the Permian fossil bearing horizons of Garhwal area are wrongly supposed to represent the Tal Formation and have suggested that the geology of the Lesser Himalaya needs rethinking. This problem clearly highlights the complex stratigraphic set up in the Himalaya. It is also equally apparent that lack of sufficiently detailed investigation has resulted in such contrasting reconstructions.

There is no published record of a palynological assemblage from the rock sequences underlying the Blaini Formation, such as the Nagthat, Chandpur and Mandhali in spite of the fact that the lithology and environment of deposition appears to be quite suitable for the preservation of palynological remains. Both intensive and extensive search of these stratigraphic sequences is also essential in order to understand their precise stratigraphic position and also to find reliable indices for their identification and correlation with equivalent rock units.

Simla Slate-Damta Unit — The Simla Group comprises a large thickness characterized by greywacke, turbidites, shales, conglomerates, quartzites, slates, limestones, and basic rocks (see Table 2; Asterisk denotes lithologies with fair/good possibility of palynomorph recovery).

The Simla Group was considered by Valdiya (1970) to be a flysch deposit, based on sedimentary structures and lithology. Sinha (1976) subdivided the Simla sequence into four distinct lithotypes — terrigenous, terrigenous carbonates, carbonates and rhythmites, which suggest a flyschoidal nature rather than true flysch deposition. In Simla Hills, the Simla slates physically overlie the Shali Unit, whereas the Damta Group (Rupke, 1974) which resembles Simla rocks both in lithology and facies, physically underlies the Deoban Unit (= Shali Unit). The stratigraphic position of Simla Slate-Damta Unit vis-a-vis Shali-Deoban Unit is, therefore, another major stratigraphic problem of the Lesser Himalaya. Simla Slate Unit (= Damta Unit) is generally regarded as unfossiliferous, except for sporadic occurrence of stromatolites in the limestones. An Upper to Middle Riphaen age was assigned (Sinha, 1977) to the Kakarhatti and Naldera limestones of Simla Group in Simla Hills, on the basis of stromatolites alone. The Simla sequence contains enough rock types (especially the rhythmites) which appear to be very favourable for palynological investigations. A detailed and systematic palynological investigation of this unit may lead to the discovery of palynofossil assemblages which may help to resolve the age of this controversial rock group.

Shali-Deoban Unit — The Shali Formation exposed in the Shali window of Simla Hills, Himachal Pradesh is characterized by the succession given in Table 3. (Asterisk indicates lithological types which may be

TABLE 2 — LITHOSTRATIGRAPHY OF THE SIMLA GROUP

(Srikantia & Sharma, 1971)

Rock units		Lithology	Thickness (in metres)
Sanjauli	Upper	Conglomerate, grit, sandstones, orthoquartzite, *grey and purple shales.	1600
	Lower	Greywacke, sandstone and *siltstones, *shale and *siltstone alternation, orthoquartzite.	
Chhaosa		*Grey, *olive-green and purple shales, *siltstone alternation, greywacke, *siltstone and orthoquartzite.	1300
Kunihar		*Shale and *siltstone alternation, with limestone interbeds (" Kakarhatti limestone ").	450
Basantpur	D	Thick-bedded to platy, greyish-blue limestone with interbedded *shales (local facies).	180
	C	Massive to bedded limestone and dolomite (local facies). ("Naldera limestone")	250
	B	*Shale, *siltstones with interbeds of lenticular limestone, sporadic *carbonaceous shale, impersistent bands of quartzite and dolomite (" Chail ").	600
	A	Greyish white quartzite and conglomerate (sporadic).	19
......Unconformity......			
Shali		Sundernagar Formation and Mandi-Darla volcanics	

TABLE 3 — LITHOSTRATIGRAPHY OF THE SHALI FORMATION

(Srikantia & Sharma, 1969)

Rock units	Principal Lithology
Bandla	*Shales, *siltstone, and quartzite breccia.
Parnali	Cherty dolomite, *grey limestone and white quartzite.
Marki	*Shales-slates, thinly-bedded limestone, quartzite, and sporadic cherty dolomite.
Tattapani	Cherty dolomite, slaty limestone and *shales.
Sorgharwari	Pink to grey limestones, sporadic *greenish to red shales.
Khatpul	Massive dolomite, *greenish to red shale at the base.
Khaira	Purple and at places white quartzites.
Ropri	Brick-red shale, *siltstone, impersistent dolomite and salt.
......Unconformity......	
Mandi volcanics	Volcanic flows, and intrusives.
Sundernagar Formation	White, purple quartzite, *slate, *phyllite.

potentially productive horizons for palynomorph recovery).

Valdiya (1964, 1969) correlated the Shali Formation with the Deoban Formation of Kumaun. Rupke (1974) on the other hand subdivided the Deoban Formation into lower, middle and upper members and correlated them with the Chandpurs and Basantpurs. The Buxa Group of Eastern Himalaya (Acharyya, 1971) has also been correlated with the Shali-Deoban Unit (Valdiya, 1973) based on gross lithology and the occurrence of similar forms of stromatolites. This indicates that the carbonates and associated sediments of the Shali Formation, the Deoban Formation and the Buxa Formation might form a continuous belt extending from Kashmir to Eastern Himalaya. The sediments of this belt appear to have been deposited in a shallow basin or under a shelf tidal-flat environment. The carbonate horizons of this belt have been assigned a Middle Riphean age (Valdiya, 1962; Raha & Sastry, 1973; Sinha, 1977) on the basis of stromatolites. There is, however, a strong scepticism about accepting stromatolites as an age-marker because sufficient work has not been done in India on this group of organo-sedimentary structures, which might permit any degree of reliance. Geologic credibility of a Riphean dating for the Shali Formation, based on stromatolites alone, is further questionable in the light of the discovery of fenestellid bryozoa of Palaeozoic age from the lower limestone unit of the Shali Formation (Rastogi, 1973). With newer data, the age and stratigraphic position of the Shali-Deoban Unit is becominge ven more controversial than in the past. One of the shale samples from the Shali Formation examined by the author yielded some good acritarchs indicative of Ordovician-Silurian age for the shale member of the Shali Formation. A detailed study of this sequence is planned. The recovery of palynological remains by Gyan Prakash (1974) from the carbonate and calcareous formations of Chaukhutia and Pipalkoti area is another indication that the Shali-Deoban Carbonate sequence of Kumaun Himalaya and its equivalent Buxa Group in Eastern Himalaya hold promise of useful palynological finds which would help in a more precise dating and correlation of the carbonate sequences of Himalaya. The sub-tidal to shallow-shelf environment of this unit appears to be favourable for the preservation of palynological remains. The Sundarnagar Formation or the Infra Shali Formation in the Simla Himalaya is characterized by volcanics in association with orthoquartzites which also indicates tidal to sub-tidal environment of deposition. There is also considerable difference of opinion regarding the stratigraphic position of these rocks, which may be satisfactorily solved, if some palynofossils are discovered from any of the slaty or phyllitic horizons of this rock sequence.

Crystalline Klippen Unit — Several detached outliers of metamorphic rocks occur as Klippen on the sediments of the Lower Himalaya. In Kumaun Himalaya, these Klippen occur as the Simla-Chor Klippe; in Mussoorie syncline as the Banali and Satengal Klippe; then there are the Dudatoli-Almora-Lohaghat Klippe, the Garhwal Nappe and the Baijnath-Askote Klippe. These Klippen are made up of metasediments with granite gneisses and bands of epi- to meso-grade rocks. The pile of metamorphic sediments of these Klippen rests over different sequences of the Lesser Himalayan zone with a thrust contact. They even show inversion of metamorphism, i.e. metamorphic grades increasing upward. The precise ages and stratigraphic position of these metasediments remain uncertain for the most part.

Recent report of palynofossils from the Jutogh Formation of Simla Himalaya (Sah *et al.*, 1977) has therefore an important bearing on the application of palynological method on the crystalline rocks of Himalaya. These palynofossils (algal sphaeromorphs) were found in carbonaceous phyllites. Similar metamorphosed carbonaceous sediments occur in various parts of the crystalline nappes and thrust sheets in the Western Himalaya requiring both intensive and extensive search for plant microfossils in the low grade metamorphic rocks which is likely to yield fruitful results.

Another controversial rock group in the Lesser Himalaya is the Chail Formation and its equivalents. The Chail Formation is also characterized by carbonaceous rocks and graphitic phyllites. Some of these rock types may yield palynomorphs in view of the low grade of metamorphism. Report of gymnospermous wood fragments from the crystallines of Bhikiasain area of Almora by Powar and Phansalkar (1971) further strengthens the hope that a thorough search for palynofossils might lead to more definite evidences for dating these stratal sequences. Powar and Phansalkar (1971) correlate the Almora phyllites with those of the Jaunsar Group after estimating an Upper Devonian to Post Devonian age based on the presence of these wood fragments. Such an estimation of age and correlation is tenuous and needs substantiation. Srikantia and Sharma (1971) equate the Chandpur Formation of the Jaunsar Group with the Chail Formation of the Simla Klippe. Such a correlation also needs further confirmation and the only possibility for obtaining reliable confirmation is through the search for palynofossils. Occurrence of similar wood fragments or more definite microfossils would not only solve the controveısy of strike continuation but the age problem as well.

3. Higher Himalaya

The crystalline rocks (Vaikrita Group) of the Higher Himalaya form a more or less continuous belt extending right from Kashmir to the easternmost extremity of Arunachal Pradesh. The sediments pile up a thickness approximating about 15-20 km. The southern limit is marked by the Main Central Thrust. The main constituents of this zone are the complex sequences of gneisses and schists, but the plutonic and sedimentary rocks are also known, which have been estimated by Gansser (1974) comprising about 10% of the total.

The high degree and three- to four-fold phases of deformation in the Central Crystalline rocks clearly reflects that the High Himalaya may constitute an unpromising area for palynological studies. The reported occurrence of plant remains from the phyllites of Bhikiasain area of Almora raises some hope that intensive search of the less metamorphosed sedimentary rocks and probably even the crystalline rocks of this zone may yield some palynofossils bearing horizons. Such a find will go a long way in fixing the age of some of these rock sequences which, in turn, will help to resolve some of the complex and complicated correlation problems in the Central Crystalline Zone of the Higher Himalaya.

4. Tethyan Himalayan Basin

The Tethyan belt of Himalaya exposes an almost continuous Cambrian to Cretaceous sequence. These rocks contain rich assemblage of invertebrate fossils and form a more or less continuous zone from Kashmir to Bhutan. The Tethyan Himalayan basin is bound towards the south by the Central Crystallines and on the north by the late Mesozoic-Cenozoic ophiolite and flysch deposits of the Indus-Tsangpo Zone. The stratigraphy of the Tethyan region is well-known and close parallelism exists between the lithostratigraphic divisions and biostratigraphic zones right from Kashmir to its eastern most exposures. Considerable agreement therefore appears to exist in the stratigraphic reconstruction and geological history of this basin. The Pre-Cambrian-Cambrian boundary, in terms of lithostratigraphy, has yet to be established. In Kumaun, this boundary is also uncertain but generally assumed to be above the Ralam conglomerates (Heim & Gansser, 1939; Shah & Sinha, 1974). A conglomerate horizon does not occur in Spiti where the Upper Haimantas (Cambrian) are supposed to grade downward with an increase in the grade of metamorphism into the metamorphics. The slaty and phyllitic horizons of Martoli and Garbyang formations could be fruitfully taken up for the search of acritarchs and other Pre-Cambrian-Lower Palaeozoic forms. Recent studies on trace fossils (Banerjee *et al.*, 1975) indicate that persistent search in these horizons for fossils might yield productive horizons which would help in the delineation of this boundary. Lack of well-defined faunal and other megafossil records has also greatly aggrevated age determination and correlation of equivalent sequences in Nepal and Darjeeling-Bhutan Himalaya.

The Hercynian epeirogenic event, marked by widespread uplift, volcanic activity, and deposition of Gondwana type sediments, can also be studied and their precise relationship established. In many areas the age and precise relationship of such sediments is uncertain. Palynological investigation of these rock sequence can also throw light on the environment of deposition and climatic conditions prevailing on the southern margin of the Tethys. It is generally assumed that the Tethyan rocks as a whole are geosynclinal and of deep-water origin. Recent discovery of sedimentary structures indicate very shallow and even epicontinental to marginal environment of deposition which increases the possibility of obtaining palynological assemblages from the Tethyan sediments.

The Triassic-Jurassic sequence in the Tethyan region is represented by black shales and limestones. These are characterized by natural gas showing at Mukti Nath in Kali Gandaki basin. These sediments could be potential source for oil and natural gas. Palynological studies may help to fill in the gaps where faunal evidences are missing or indistinct because of type of facies.

The Cretaceous is a period of traumatic geological activity and consequently a variety of rocks are exposed in different parts of the Himalaya. In Spiti, we have a sandstone sequence while in Sikkim it is represented by flysch sediments with a limestone-shale sequence. In the Cretaceous rocks of Kali Gandaki basin Upper Gondwana fossils have been reported which indicate shallow lacustrinal deposition followed by uplifting. All these rock groups have still to be searched for palynological fossils. Thus, in the Tethyan Zone the entire Phanerozoic, i.e. Cambrian, Ordovician, Silurian, Devonian, Permo-Carboniferous, Triassic, Jurassic, Cretaceous, and even younger horizons, could be explored for palynofossils to help to establish a more useful biostratigraphy and to better understand the Baicalian, Caledonian, Hercynian, and the Alpine-Himalayan orogeny.

5. Indus Suture Zone

A narrow belt of basic to ultra-basic rocks and sediments, ranging from Cretaceous to Mio-Pliocene in age, occurs north of the Tethyan region along the Indus Suture. The Cretaceous sediments are flyschoid in nature though younger rocks show a mollasic aspect. There is some controversy regarding a flyschoid or a mollassic nature of these rocks. A search for vertebrates along with palynological remains in these sediments could throw significant light on the palaeoenvironments of these sediments. The shaly bands in the flysch sequence hold good promise of yielding pollen and spores which could help not only in establishing their age but might aid in the biostratigraphic subdivision of this sequence as well. Recently, Bhandari *et al.* (1977) have worked out the stratigraphy of the Ladakh Mollasse Group and have been able to further subdivide it into Kargil, Tarumsa and Pashkyum formations. Rich fossil assemblages have been recovered by them from all the three formations.

The Kargil Formation has yielded radiolarian genera like *Sethodiscinus* sp.; nannofossil species *Curvidiscoaster nobilis*; and an ostracod genus *Krithe* sp. These fossils indicate Palaeocene to Lower Eocene age for this formation. The overlying Tarumsa Formation yielded palynofossils like *Magnastriatites* cf. *M. howardii*, *Lycopodiumsporites* spp., *Caratosporites*, *Pinuspollenites*, *Tricolpites*, *Caryspollenites simplex*, *Betulaceoipollenites* sp., *Engelhardtioipollenites*, *Ulmipollenites* cf. *U. undulosus*, *Alnipollenites*, *Juglanspollenites*, *Polyporina*, *Araucariacites* sp., *Pediastrum* sp., etc. which indicate a Oligocene-Miocene age for the formation. The uppermost stratigraphic unit or the Pashkyum Formation yielded foraminifers only, which indicate recycling and Cretaceous-Eocene derivation.

Thus, in summary it can be said that the Himalayan sediments offer enough scope for the application of palynology in the resolution of various geologic problems which await solution. To make palynological method really useful in solving various problems of Himalayan stratigraphy the first essential requirement will be the establishment of palynological assemblages from type sections or well-dated sections. Correct identification of individual taxa and a precise understanding of their affinities is another prerequisite which will add greatly to the details of environmental and palaeoclimatic interpretations and also provide a basis for correlation outside the immediate area of investigation. Key species have to be identified which will permit distinction among various levels of the rock sequences. Experience has shown that conclusions derived from isolated samples are generally liable to become a great source of misinformation. These preliminary studies should, therefore, be adequately supplemented by detailed investigations of as many measured stratigraphic sections as an area may present. These studies will provide range charts, showing the distribution and abundance of marker species which will probably indicate their value for basinal, regional or inter-regional correlations. Only detailed statistical analysis on stratigraphic sections will permit finer subdivision of the sequences, which in turn, might yield correlative horizons (biozones). These biozones when traced laterally, may even help in identifying useful time planes. Lastly, only intensive and extensive studies can provide much needed information on the sedimentary relations, geologic history and palaeogeographic reconstructions.

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