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SPOROLOGICAL DATING OF NON-MARINE SEDIMENTARY ROCKS IN INDIA[1]

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ABSTRACT—The possibility of using the spore contents of the non-marine sedimentary rocks for their dating has been advocated on the basis of such studies made in India during recent years. The palynological information from pre-Gondwana, Gondwana and post-Gondwana sediments of the Indian subcontinent has been synthesized and adduced in support of this palaeobotanical parameter for geological dating.

INTRODUCTION

During the last two decades the study of spores and pollen grains interbedded in sedimentary rocks of lacustrine, fluviatile, estuarine or neritic origin has increasingly gained in importance for geological work. Five factors have mostly contributed to this enhanced interest, viz., (1) that the spores and pollen grains present in rocks are mostly those of the vegetation growing at the time of sedimentation; (2) that the spores and pollen grains being microscopic are available in large number in small amount of suitable rock samples; (3) that the walls of spores and pollen grains are resistant to normal physical and chemical agents of destruction and thus, are recoverable in undamaged condition for study; (4) that the spores and pollen grains are endowed with many morphological variations in their nature and organisation among the various classes of plants, enabling their detailed classification and consequently ease in identification and (5) that the spores and pollen grains have changed their nature and organisation due to evolution in the course of geological time. These qualities have established *sporae dispersae* as an excellent means of dating of non-marine sedimentary rocks.

The possibility of utilizing plant microfossils including dispersed spores for the dating of sedimentary rocks was realized some decades ago in India. Sahni (1947) indicated the potentialities of micropalaeobotanical investigations of Indian sedimentary deposits of unknown or disputed age for their dating. Under his guidance such sediments as the Purple Sandstone (Hsü, 1946), Neobolus Shale (Lakhanpal, 1950), Magnesian Sandstone (Bharawdaj, 1950) and Salt Pseudomorph Beds

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Sahni *et al.* (1951) of the Salt Range area were investigated for the plant microremains. The results of these investigations through lack of such spores as are found in sediments of younger ages, confirmed their older age. Subsequently Ghosh and Bose (1950a, 50b, 52), Sitholey, Srivastava and Verma (1953), Jacob *et al.* (1953), Sahni and Shrivastava (1958), Sastry and Venkatachala (1968) and Maithy (1969) published their findings on the Vindhyans, Cambrian of Salt Range, Kashmir and also Cuddapah sediments.

Our knowledge of the dispersed spores from Indian sediments commenced with Virkki (1937, 39) who described some spores from L. Gondwana rocks of the Salt Range. This was followed by a progressively increasing number of works on dispersed spores from sediments of different ages ranging from Permian to Tertiary. Those who contributed for the Permian are Virkki (1946), Sen (1944, 1953), Mehta (1944), Ghosh *et al.* (1947, 48), Pant (1950), Goswami (1952), Surange *et al.* (1953, 1956), Guhasarkar (1956), Datta (1957), Bhattacharya (1957, 59), Das (1958), B. Bhattacharya (1959), Ganguly (1959), Potonié and Lele (1961), Ghosh (1963), Bharadwaj and his associates (1962, 64, 64, 64, 65, 65, 65, 65, 66, 66, 68), Tiwari (1964, 65, 67,68), Venkatachala *et al.*(1964, 65,66,66, 66a, 68, 68a, 68b), Lele (1964, 64, 65, 69), Salujha (1965), Maithy (1965, 66, 68), Kar (1966, 67, 68, 68a, 68b, 69,), Navale and Tiwari(1966, 67) and Maheshwari (1967, 67a).

The *sporae dispersae* of the Triassic is rather scantily known from India. The only contributors are Sitholey (1943, 51, 54), Lakhanpal *et al.* (1960), Ghosh and Srivastava (1962), Shrivastava and Pawde (1962), Chandra and Satsangi (1965), Sah *et al.* (1968), Bharadwaj and Srivastava (1969) and Kar (1970, 70a).

The Jurassic and Cretaceous *sporae dispersae* has been described by Rao (1943), Jacob *et al.* (1952), Jain *et al.* (1966, 69), Vishnu-Mittre (1954), Ramanujam (1957), Dev (1961), Srivastava (1963, 66), Ghosh (1964), Singh (1964, 66, 66), Sah (1955, 65, 67), Kar *et al.* (1970), Varma (1964), Venkatachala (1966, 67, 69, 69a, 69, 69. 70a). and Bharadwaj (1969).

The dispersed spores and pollen grains from Tertiary rocks have been described by Chitaley (1951), Rao *et al.* (1950, 52), Vimal (1952, 53), Potonié and Sah (1960), Ramanujam (1960, 66), Baksi (1962, 65), Biswas (1962), Ghosh and Banerjee (1963), Banerjee (1964, 65, 66), Sah and Datta (1966, 68).

The pre-Gondwana sporae dispersae

Among the important, pre-Gondwana, non-marine sedimentary formations of India are the Cuddapahs and the Vindhyans. The spores dispersed in quartzitic sandstones with thin carbonaceous laminations, belonging to Cuddapahs, have been described by Sahni and Shrivastava (1958). Out of the 11 spore kinds described, two are more than 300 μ in size and hence presumed to be megaspores of some sort. Among the rest, three are presumed to be monolete bearing, two trilete bearing and four without any haptotypic mark. Unfortunately the illustrations are too poor to confirm the observations of the authors. However, the bodies described and illustrated, do appear to be of organic origin and probably plant spores. The upper part of Vindhyan System which is of non-marine sedimentary origin has been studied for the plant microremains by Sitholey, Srivastava and Varma (1953). These authors have found only algal remains out of Suket shales and Sirbu shales. Ghosh and Bose (1950a) have reported the occurrence of some monolete bearing, sub-circular spores from Olive shales of Semri Series (Upper part of Lower Vindhyans). There are also on record some finds of spores in the pre-Gondwana sedimentary rocks of Kashmir and the Salt Range. Ghosh and Bose (1952) reported the presence of psilate, oval spores of unknown affinity and winged spores comparable to some gymnospermous pollen grains, from the Cambrian of Kashmir. Ghosh and Bose (1950b) recorded the winged spores from Neobolus shales (Cambrian) of Salt Range.

Recently, Sastry and Venkatachala (1968)[1] and Maithy (1969) have published very interesting and detailed information on the palynology of Vindhyan rocks. Sastry and Venkatachala (1968) have studied the pre-Siwalik sequence met with in a number of borings in the Ganga Valley. In these borings, below the Siwaliks, an unconformity appears uniformly at different levels, separating an underlying sequence of sedimentary rocks resting on a metamorphic sequence of phyllite and quartzite. These metamorphics at a depth of 2115-2119 m have been dated by Potassium-Argon method to be about 1045 million years. In the pre-Siwalik sedimentaries, from one of the deep wells, at 1750-52 m, a trace fossil *Diplocraterian*, earlier known from Cambrian and Lower Carboniferous, has been discovered in the limestone. Immediately overlying this limestone, plant spores and other remains have been recovered from shales and siltstones. The spores are all simple, trilete bearing, circular or triangular, laevigate bodies. Some sphaeromorphs, ranging in size from 20-150 microns are also present. The authors conclude the age of the pre-Siwalik sedimentaries to be Palaeozoic (Carboniferous or Pre-Carboniferous). In so far, as the palynological evidence is concerned, the exclusive presence of primitive, simple, trilete spores points to a definitely pre-Devonian age because the spore floras by Devonian times, had become quite diversified. In view of the trace fossil *Diplocraterian* being known from as old deposits as the Cambrian, and that the spore flora presents a much more primitive aspect than that of the Devonian times, the age of the Ganga Valley sediments under consideration seems to lie between Silurian and Cambrian. The micro-remains found by Salujha *et al.* (1967) in these sediments (but for the supposedly disaccates which may not be so) are quite closely comparable to those from Cambrian strata (cf. Andreeva, 1966a) in U. S. S. R. However, the spore assemblage described by Sastry and Venkatachala (l.c.) contains a few triletes the like of which are not known so far, from strata older than the Silurian.

The other publication by Maithy (1969) relates to the plant microremains from Suket shales, considered by some to be the bottom most horizon of Upper Vindhyans, but top most of Lower Vindhyans by Misra (1969). These microremains totally lack the spores of land plants and instead, consist of only acritarchs and *Gloeocapsamorpha*, an alga. Some of these acritarchs (*Protoleiosphaeridium*) are similar to those recovered by Sastry and Venkatachala (1968). On the basis of his find of acritarchs in Suket shale, Maithy

1. Read at the Symposium on 'Dating of Rocks' Geology Section, 56th Indian Sci. Congress, Bombay, Jan. 1969.

thinks these shales to be of Ordovician age presuming the same to be the last known dated occurrence of Acritarcha. However, now these are well known form of the Pre-Cambrian (Andreeva, 1966). Moreover, the absence of any primitive, triletoid spores as are already known from the Cambrian (Andreeva, 1966a), also suggests greater antiquity of the Suket shales. Acritarchs represent very low type of planktonic vegetation, close to algae. They originated in the Pre-Cambrian and evolved very slowly. It seems that the same has been the case with trilete spores in the beginning. Here one must realize a subtle fact that all primitive life evolved or diversified very slowly in ancient times as compared to what we find later in the earth history with respect to more highly evolved life.

Misra (1969), recently synthesized all the evidence available on absolute dating of some Vindhyan rocks. Accordingly, on the basis of Potassium-Argon studies made by Vinogradova and Tugarinov (1964 in Misra, 1969), the Vindhyan System dates back from 1400 million years. On the other hand, Sarkar *et al.* (1964) think that Vindhyans are younger than 600 million years because the unconformably underlying Malani Rhyolite is 783-600 million years old. It seems that the Vindhyan sedimentation started more than a billion years or so earlier and continued protractedly for several hundred million years.

Sporologically, the topmost horizon of Semri Series (Suket shales) appears fairly ancient and could well have been deposited during the Algonkian. The Upper Vindhyans, on the other hand, appear to have commenced deposition in the Cambrian and continued thereafter for sometime.

From the above discussion it is apparent that the sporological finds in pre-Gondwana rocks of India though few and rather little appreciated, do provide a tangible basis for the dating of various ancient formations. Further they point out to the possibilities that a concerted effort on the study of various shales in the Vindhyan succession with the help of newer techniques, could establish their precise age and also that certain spore and acritarch kinds might reveal themselves ultimately as indices for the various horizons in these, oldest, Indian sedimentary rocks.

Lower Gondwana sporae dispersae

During the last one decade coals and shales belonging to Talchir and Damuda Series of the Lower Gondwana succession in India have been exhaustively studied for their spore contents. A few years back, I (Bharadwaj, 1966) synthesized all the then available palynological information on the distribution of spores and pollen grains in Lower Gondwana sediments. It was concluded that the spore flora of Talchir Series is distinguishable from the overlying Damuda Series chiefly by the dominance of trilete-bearing monosaccate pollen grains in the former. Within the Talchir Series, the Karharbari Stage has lesser monosaccates more bisaccates than the older Talchir Stage. In Damuda Series, the Barakar Stage is dominated by triletes which are much reduced in the Barren Measure Stage. On the other hand, the bisaccates which are low in the Barakar Stage reach the maximum in Barren Measures Stage. The Raniganj Stage is marked out from Barren Measures Stage through the increase in triletes and corresponding decrease in saccates. A number of index genera for the various stages have also been mentioned.

Middle Gondwana sporae dispersae

Our knowledge of the sporae dispersae from the whole span of Middle Gondwanas is incomplete. What we know in detail is from Lower Triassic i.e. Panchet Series. Kar (1970) has described a mioflora from the basal part of Panchet and Bharadwaj and Srivastava (1969) from the upper part. The spore flora of Lower Panchet is profoundly rich in trilete spores (75%) and the gymnospermous pollen grains are much less (16%). On the other hand, the mioflora of Upper Panchet is characterised by virtual non-existence of triletes and preponderance of various kinds of gymnospermous pollen grains. This spore flora from Nidpur in Madhya Pradesh is fairly distinct qualitatively too as compared to those of Lower Panchet and Upper Raniganj Stages. Another spore flora described from a few miles up the prevailing dip and considered by Maheshwari (1967) to be belonging to Raniganj Stage seems to be representing the Barren Measures in view of the striking lack of trilete spores and richness of saccates especially *Densipollenites* in it as compared to Raniganj Stage mioflora from Raniganj area. The spore flora of Middle (Parsora) and Upper Triassic (Mahadevas) is still unknown. However, megafloristically the Parsora flora and Nidpur floras are quite near to each other in view of the occurrence of *Dicroidium* and *Glossopteris* in both of them. Hence, sporologically I am inclined to presume that Parsora mioflora if ever known, would not be very different from that of Nidpur (Daigaon Stage).

Upper Gondwana sporae dispersae

The Lower Jurassic spore flora is known from the Salt Range (Jain and Sah 1969). This contains good percentage of *Matonisporites*, *Staplinisporites*, *Tigrisporites* and *Ischyosporites* besides other triletes, and abundance of such pollen genera as *Classopollis*, *Gliscopollis*, *Spheripollenites* and *Perinopollenites*. The monocolpate pollen grains are scarce. A number of typically Rhaetic-Liassic megaspores have also been reported.

The Lower to Middle Jurassic spores have been described by Srivastava (1966) from Rajasthan. This assemblage is characterised by fair number of triletes and monocolpates, absence of coniferous saccate pollengrains but a dominance of *Classopollis*.

The Middle to Upper Jurassic spore assemblages from Rajmahal Hills, described by Rao (1943), Vishnu-Mittre (1954), Sah and Jain (1965), from Kutch by Venkatachala, Kar and Raza (1969) and from eastern coast by Kar and Sah (1970) are distinct from those of the Triassic or Lower Jurassic. They are rich or poor in pteridophytic spores associated with dominant coniferous pollen grains and lack the four, characteristic, Triassic spore genera *Nidipollenites*, *Satsangisaccites*, *Weylandites* and *Praecolpatites*. On the other hand the typical, younger Jurassic pollen grains *Araucariacites*, *Podocarpidites*, *Phyllocladidites*, *Podosporites*, *Dacrycarpites* etc. are present in each of the two distinguishable assemblages either rich or poor in triletes.

Venkatachala and Kar (1970) have been able to distinguish three palynological zones in a conformable sequence from Upper Katrol (top Upper Jurassic) into Bhuj (Lower Cretaceous) sediments in Kutch. They have found *Cycathidites*, *Concavissimisporites*, *Contignisporites*, *Applanopsis*, *Podocarpidites*, *Katrolaites* and *Exesipollenites* as characteristic of the Katrol sediments. The typical spores of the Bhuj Stage of Umia Series

(Zone 3) are *Cicotricosisporites*, *Polycingulatisporites*, *Ceratosporites*, *Staplinisporites*, *Trilobosporites*, *Coronatispora*, *Foraminisporites* besides *Applanopsis*, *Podosporites*, *Classopollis* etc., in abundance. The spore flora of zone 2 is a mixed one between zones 1 and 3. The Bhuj mioflora has also been found to occur in Dharangdhara (Varma and Rawat 1964), in Jabalpur (Dev 1961) and Karaikal (Venkatachala and Jain 1969).

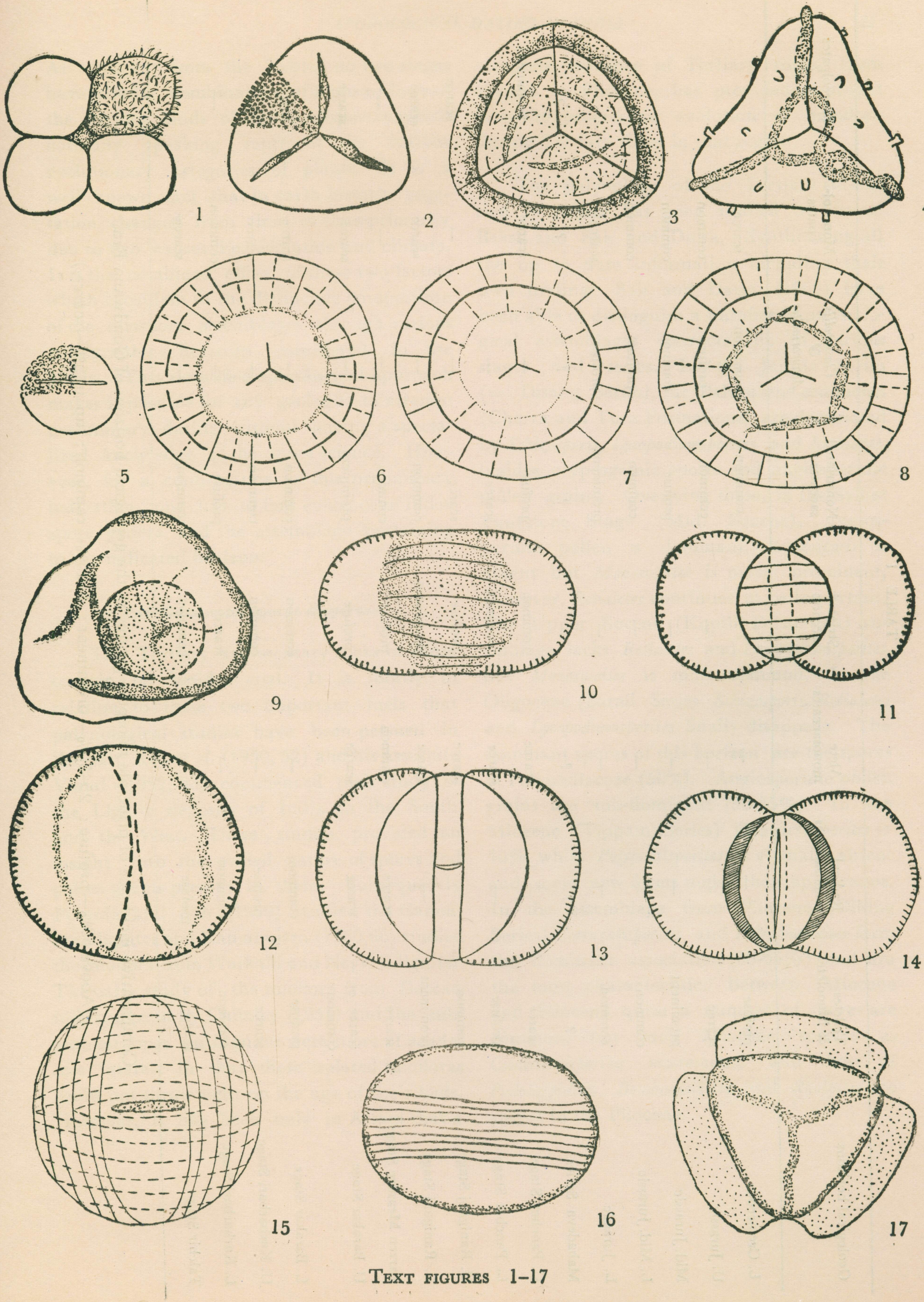
Sporological Indices in Gondwana succession

Sporological studies on the Gondwana sediments of India have proceeded so deep as to enable us date its various horizons from the data gathered at generic and supra-generic level rather than the intricate and highly technical specific level, so often employed by many workers elsewhere. Besides the characteristic assemblages already referred to here for the various horizons, certain spore genera (Text-Figs. 1-17) or groups of allied genera in their high incidence are now known to be indices for particular horizons. Thus, *Parasaccites*, *Virkkipollenites* and *Plicatipollenites* (Radial monosaccates) together representing about 50% of the total assemblage and *Quadrisporites* (3%) characterize Talchir Stage. High *Sulcatisporites* and prominent triletes distinguish the Lower Karharbari Stage. In the Upper Karharbari Stage radial monosaccates again rise and the triletes decrease significantly. *Microbaculispora* alone or in association with *Indotriradites* up to about 15% representation, is characteristic of Lower Barakar Stage. Upper Barakar Stage stands out by high representation of striate bisaccates or *Sulcatisporites*. For Barren Measures Stage, *Densipollenites* (10-25%) with few triletse but abundant striate bisaccates is diagnostic. In Raniganj Stage triletes and striate bisaccates are almost equated and *Indospora* and *Thymospora* attain their maximum (7-10%). In Lower Panchet, triletes increase appreciably. In Upper Panchet Stage *Nidipollenites*, *Satsangisaccites* and *Weylandites* reach their climax (10-20%). In Lower Jurassic *Classopollis* is most dominating and in Upper Jurassic *Araucariacites* and *Callialasporites* are most prominent. In Lower Cretaceous, *Araucariacites* wanes and cyatheaceous and schizeaceous triletes take over (Bharadwaj 1969).

Whereas the above mentioned method leads to final dating, a yet simpler way to get preliminary indication of age is provided by ascertaining the comparative abundance or scarcity of such broad groups as triletes, radial or alete monosaccates, striate or non-striate saccates, Alete nonsaccates and Mono- or Praecolpates. This needs counting of the total assemblage in terms of the above groups only. An idea, as to how this infomation provides clues to dating is given in Table 1.

EXPLANATION OF TEXT FIGURES 1—17

1. *Quadrisporites*; **2.** *Microbaculispora*; **3.** *Indotriradites*; **4.** *Indospora*. **5.** *Thymospora*; **6.** *Parasaccites*; **7.** *Virkkipollenites*; **8.** *Plicatipollenites;* **9.** *Densipollenites;* **10, 11.** *Striatopiceites* and *Striatites* (striated bisaccates); **12.** *Sulcatisporites*; **13.** *Nidipollenites;* **14.** *Satsangisaccites*; **15.** *Weylandites*; **16.** *Classopollis*; **17.** *Callialasporites*.



TEXT FIGURES 1–17

TABLE 1

Geological horizons	Triletes & Monoletes	Radical monosaccates	Alete monosaccates	Striated saccates	Nonstriated saccates	*Classopollis* & *Araucariacites*	Monocol-pates	Praecolpates
L. Cretaceous	profuse	—	—	—	common	common	scarce	
U. Jurassic	scarce	—	—	—	common	profuse	common	
Mid. Jurassic	prominent	—	—	—	profuse	common	common	
L. Mid. Jurassic	common	—	—	—	common	profuse	common	
L. Jurassic	common	—	—	—	prominent	profuse	scarce	
Mahadeva Series	?	?	?	?	?	?	?	?
U. Panchet Stage	scarce	—	scarce	common	profuse	—	scarce	prominent
L. Panchet Stage	profuse	—	scarce	common	scarce	—	—	—
U. Raniganj Stage	common	—	scarce	profuse	scarce	—	—	scarce
L. Raniganj Stage	prominent	—	scarce	prominent	common	—	scarce	scarce
Barren Measure Stage	scarce	scarce	common	profuse	common	—	—	—
U. Barakar Stage	scarce or common	scarce	scarce	profuse	prominent	—	scarce	scarce
L. Barakar Stage	profuse	common	—	common	common	—	scarce	scarce
U. Karharbari Stage	scarce	profuse	—	common	common	—	scarce	—
L. Karharbari Stage	common	common	—	scarce	profuse	—	common	—
Talchir Stage	scarce	profuse	—	common	common	—	scarce	—

Comparative incidence of principle miospore groups in the geological horizons of Gondwana Era.

(Above 50%—profuse ; 25–50%—prominent ; 5–25%—common ; up to 5%—scarce.)

As apparent from the Table, no two stages have similar combination of highs or lows of the various kinds of sporae dispersae which normally speaking represent the various evolutionary categories of plants. It is a well known fact that in earth history, vegetation changed from time to time primarily due to two causes i.e. evolution and climate. It is the combined effect of these two factors which is evident in the distinctive composition of the miospore assemblages through various stratigraphic horizons considered in the Table. This simplified sporological approach makes it possible for any geologist to attempt preliminary dating without having a specialized knowledge of the spore science. However, for a confirmation of this preliminary indication, one has to find evidence of index spore genera and the assemblage pertaining to the indicated horizon.

Post-Gondwana sporae dispersae

The Tertiary sedimentary rocks in India contain oil besides coal. It is mostly in relation to these two important fuels that palynological studies have been persued in the past. Rao *et al.* (1950, 52) and his associate Vimal (1952, 53) commenced their study of the Lignite deposits of India in the South and the West. These studies provided an insight into the varied nature of spores and pollen grains present in them. Subsequently Potonié and Sah (1960) studied the Cannanore lignites and Ramanujam (1960,66) studied the mioflora from Warkalli and Neyveli lignites. The early study of the mioflora from Deccan intertrappean by Chitaley (1951) and the subsequent ones on Lignites were more of academic interest in that these isolated miofloras could not throw light on the age of their beds. However, it has been only in Assam that a complete sequence of Tertiary rocks, from Eocene to Pliocene, has provided an insight into the progressive evolution of mioflora during Tertiary times in that region.

The palynology of the Tertiary succession in Assam has been studied by Biswas, Baksi and Sah and Dutta. Synthesizing all the up to date information including their own findings, Sah and Datta (1968) have been able to distinguish a number of palynological assemblages characteristic of various stages and series. In the Jaintia Series (= Disang Series), the Palaeocene sediments (Cherra and Tura Formations) are dominated by *Schizosporis*, *Lycopodiumsporites* and *Retialetes*, besides cryptogamic spores and angiospermic pollen grains. Overlying these, in the Sylhet Limestone Stage (Mid. Eocene), angiospermic pollen is dominant, *Schizosporis* is absent but *Monosulcites* is more prominent, However, *Retialetes* continues to be important. The Upper Eocene (Kopili Formation) assemblage lacks *Retialetes* and *Lycopodiumsporites* but *Monosulcites* is more common. In the Oligocene (Barail Series) *Schizosporis*, *Retialetes* and *Lycopodiumsporites* finally disappear. The dominant spores of this horizon are the spores of Polypodiaceae (50%). Angiospermic pollen grains are sub-dominant (30-35%). In the Miocene (Tippam Series) *Cicatricosisporites* is 40% while *Polypodiisporites* is virtually absent and some new forms make their appearance. In the assemblage from Pliocene (Dihing Series) *Corrugatisporites* and *Polygonacidites* form the dominant association (60-65%) and are the most characteristic. Between Miocene and Pliocene quite a number of spores are common, but such Miocene species as *Cicatricosisporites macrocostata* and those of *Podocarpidites*, *Bombacacidites* and *Rhoipites* are absent in the Pliocene.

From the foregoing synthesis of the available information on the palynological contents of the non-marine sedimentary rocks of India it is apparent that spores and pollen constitute a reliable parameter for dating. Major ground has already been covered through the efforts of Indian palyno-stratigraphers so that the changing patterns of the plant-life through the various ages in India as reflected sporologically, is already known. The pre-Gondwana sediments are still to be tackled determinedly.

Today, sporological approach appears to be fairly easy only because we already know sufficiently, yet we have to cover more ground to attain confidence with regard to finer stratigraphic dating involving different depositional environments in various ages throughout the country.

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