# PHYTOGEOGRAPHIC EVOLUTION OF GUTTIFERAE AND ITS BEARING ON THE PAST CLIMATE

U. PRAKASH

Birbal Sahni Institute of Palaeobotany, Lucknow

## ABSTRACT

Phytogeographically Guttiferae is an important tropical family with fossil records going back to the Upper Cretaceous. It was widespread during the Tertiary and was known even from Europe and Central United States, which are presently devoid of Guttiferous plants.

## INTRODUCTION

DURING the early part of the Lower Cretaceous the continental flora has the same composition as that of the Jurassic, i.e. it was a flora of cycads, ginkgoes, conifers and ferns in which the Benettites developed to a considerable extent. However, in the second half of the Lower Cretaceous new elements were added to this typical Mesozoic flora which included few representatives of the angiosperms that appeared in the Barremian. Since then the angiosperms started appearing in great numbers and in wide areas so that from the base of the Upper Cretaceous the angiosperms dominated over the gymnosperms and maintained a dominant position in the continental flora.

One of the phytogeographically important tropical families of the angiosperms is Guttiferae; this appear to show its presence in the Cretaceous. Seeds of *Mammaeites franchetis* are known from the Upper Cretaceous of France (Fliche, 1896). These resemble those of the modern genus *Mammea*. This is the first record of a guttiferous plant in the geologic history of this family.

It is said that at the end of the Lower Cretaceous and beginning of the Upper Cretaceous the Gondwana disintegrated and mostly sank beneath the sea level. However, such fragments of the Gondwana as Indian, Australian, African, South American platforms existed in their contemporary forms. Contemporaneous with the Upper Cretaceous transgression, large scale volcanic processes occurred in subsiding parts of the Gondwana, such as in Africa and India.

## GEOLOGIC HISTORY

### TERTIARY

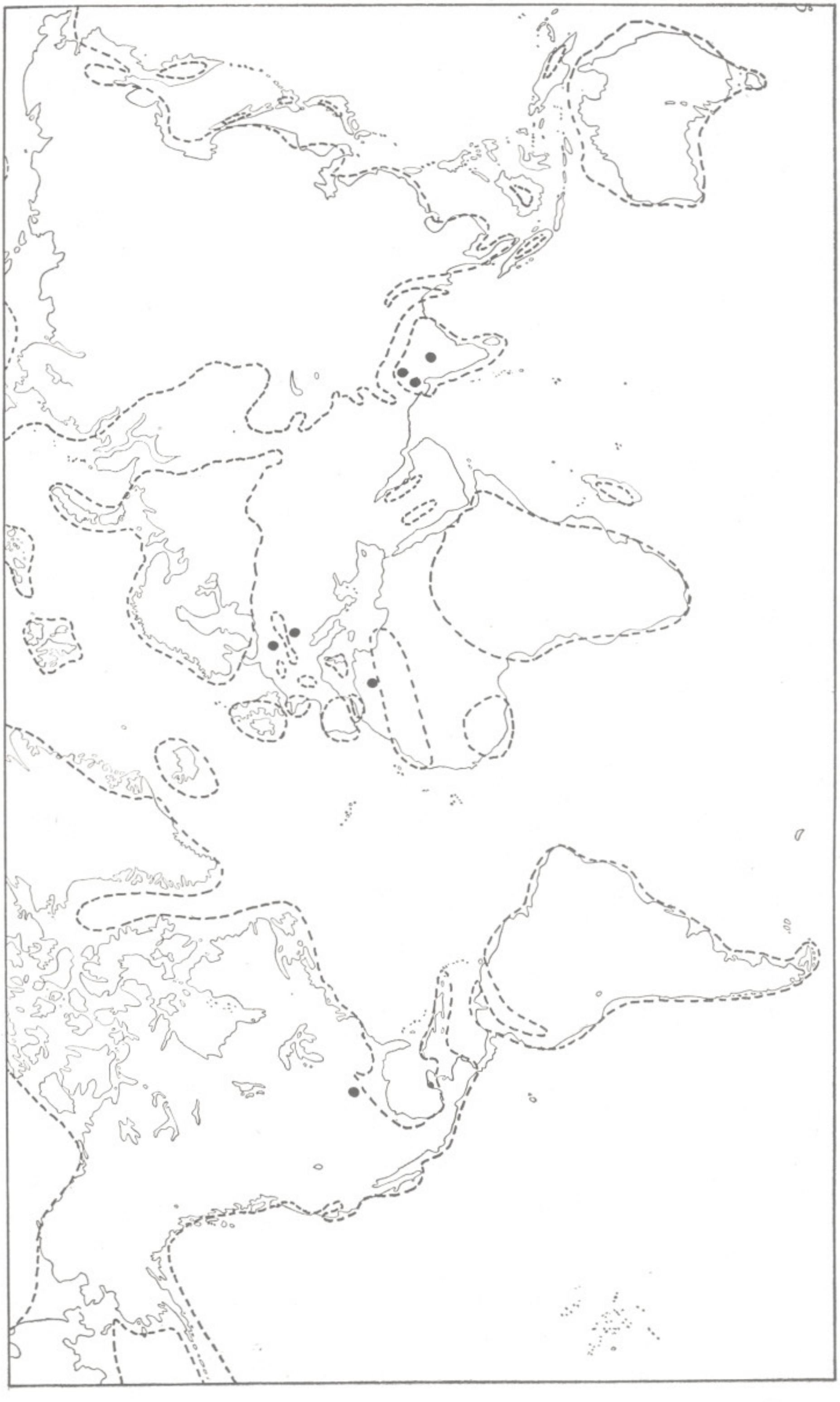
The study of the Tertiary indicates that the Palaeogene differs in organic as well as in physicogeographical assemblage from the Neogene.

#### PALAEOGENE

During this period two phytogeographical provinces were known. The first included Western Europe, the southern part of the Russian platform upto Stalingrad and southern Asia (in the tropical and subtropical areas). In the new world Mexico is included in this province together with the adjoining temporary tropical and subtropical zones. The second phytogeographical province covered the extra tropical part of Asia and North America, as well as the present Arctic zone (Strakhov, 1962). Gondwana no longer existed as a separate entity during this period. Most of its territory was deeply submerged under the waters of the Atlantic and Indian Oceans. A smaller part of this land was preserved as small fragments forming the contemporary South American, African, Indian and Australian platforms (Map 1).

In this period the family is known to occur in North America, Europe, Africa and India (Map 1; Table 1). The earliest records are from the Early Eocene of the Deccan Intertrappean series in India.

From the Deccan Intertrappean beds, a woody tetralocular dicot fruit, *Indocarpa intertrappea*, is known from the well-known locality of Mohgaon Kalan (Jain, 1964). This fruit could not be compared to any living genus and has been tentatively assigned to the family Guttiferae, showing some resemblances to those of the Hypericoideae and Clusoideae. A fossil wood said to resemble *Clusia* and *Tavomita* is also recorded from Mahurzari (Shallom, 1963) in the Deccan Intertrappean series. Recently, some pollen grains



MAP 1 — Geographic distribution of guttiferous fossil plants (black dot) and palaeogeography of the Palaeogene (marked by dotted line).

showing resemblance to those of *Calophyllum, Platonia* and *Kielmeyera* have been recorded from the Palana lignites of Lower Eocene age in Rajasthan (Sah & Kar, 1974). From the Middle Eocene beds of Fuller's earth at Kapurdi in Western Rajasthan, Lakhapal & Bose (1951) described leaf impressions comparable to *Mesua* and *Garcinia* and fruits somewhat resembling to those of *Calophyllum trapezifolium, Garcinia* and other guttiferous plants. On further examination the leaf impressions revealed a close resemblance to the modern leaves of *Mesua ferrea* and *Garcinia lanceaefolia*. Those resembling *Mesua ferrea* have been described as *Mesua tertiara* and the others resembling *Garcinia lanceaefolia* are assigned to *Garcinia borooahii* (Lakhan-1964). Of the three types of fruits reported pal, earlier (Lakhapal & Bose, 1951) from the same deposits, the one with a globose shape and thicker outer wall shows similarity with the fruits of *Garcinia* and has been assigned to fossil species, *G. borooahii* (Lakhapal, 1964).

A fossil wood somewhat resembling that of *Garcinia* is also known from the Palaeogene continental deposits of Algeria in Africa (Delteil-Desneux, 1970).

Leaves resembling those of *Clusia* are known from the Lower Eocene of Wilcox group in Arkansas, U.S.A. These have been named as *Clusiaphyllum eocenicum* by Berry (1930).

Some guttiferous leaves have also been recorded from the Eocene nodular stones of Mosel near Saxony in Germany (Fischer, 1950). These have been named as *Guttiferaephyllum moselense* resembling the modern leaves of *Kielmeyera corymbosa* (trop. South America), *Clusia sellowiana* (trop. South America) and *Clusia peruviana* (Andes); *Guttiferaephyllum oblongum* resembling *Tavomita leucantha* (trop. South America) and *Garcinia petiolaris* (Malayan); and *Guttiferaephyllum* sp. resembling some species of *Clusia* growing in tropical South America.

In 1952 Hofmann recorded a fossil wood as *Guttiferoxylon prambachense* from the Upper Oligocene of Prambachkirchen in Austria.

## NEOGENE

The uplifting processes at the end of the Palaeogene drove the sea from the contemporary fragments of the Gondwana and continued later on becoming stronger during the Neogene. At that time South American, African and the Indian platforms were entirely continental and were only covered by water along their narrow marginal areas (Strakhov, 1962).

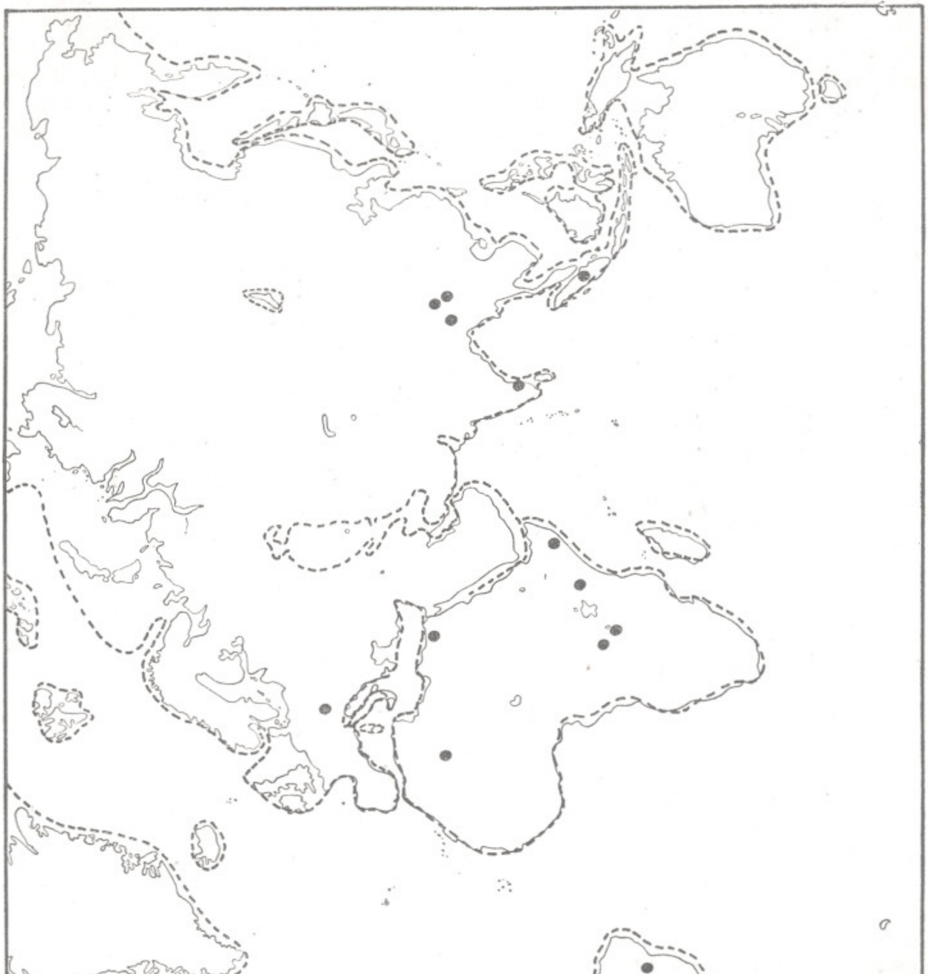
Continental and marine organisms gradually attained characteristic features similar to those of present day forms. During this era the family Guttiferae is known to have occurred in Africa, Europe, India, Indonesia and South America (Map 2; Table 1).

In 1932 Bancroft described a fossil wood from the Miocene of Karungu in Kenya, East Africa and named it as *Dryoxylon symphonioides*, the specific name indicating some relationship with the modern woods of *Symphonia*. However, Chiarugi (1933) thinking it to be a wood of *Symphonia* transferred it to *Symphonioxylon symphonioides*. On further detailed examination of this and a fossil wood from the Oligo-Miocene of Egypt, Krausel (1939) described it again as *Guttiferoxylon symphonioides*, the name showing affinity with the guttiferous plants. He further described another fossil wood as *Guttiferoxylon fareghense* from the Lower Miocene of Egypt showing resemblance to both *Mesua* and *Calophyllum*. From the Pontien (?) of Sudanese Algeria in Africa, Boureau (1952) described a fossil wood as *Guttiferoxylon saharianum*. Two fossil woods of *Symphonia* are also known from the, ?Plio-Pleistocene of Somaliland in Africa. These are described as *Symphonioxylon stefaninii* and *S. scecgureensis* (Chiarugi, 1933).

Recently Lakhanpal (1966) described a leaf impression of *Garcinia* from the Middle Tertiary beds of South Kivu in Congo. This resembles closely the modern leaves of *Garcinia kola* growing at an altitude of about 500 metres in Cameroons and Congo. Pollen grains resembling those of *Platonia* are known from the Neogene of Burundi, Rusizi Valley in Congo (Sah, 1967; Sah & Kar, 1974).

Guttiferae was also represented in Europe during the Neogene. Hofmann (1944) recorded a fossil wood, *Guttiferoxylon garcinioides*, from the Miocene beds of Prambackhirchen in Austria. This resembles the modern woods of *Garcinia cowa* and *G. mannii*.

Guttiferous plants are also known from the Late Tertiary of Colombia in South



MAP 2 — Geographic distribution of guttiferous fossil plants (black dot) in the Neogene and palaeogeography of the Upper Pliocene (marked by dotted line).

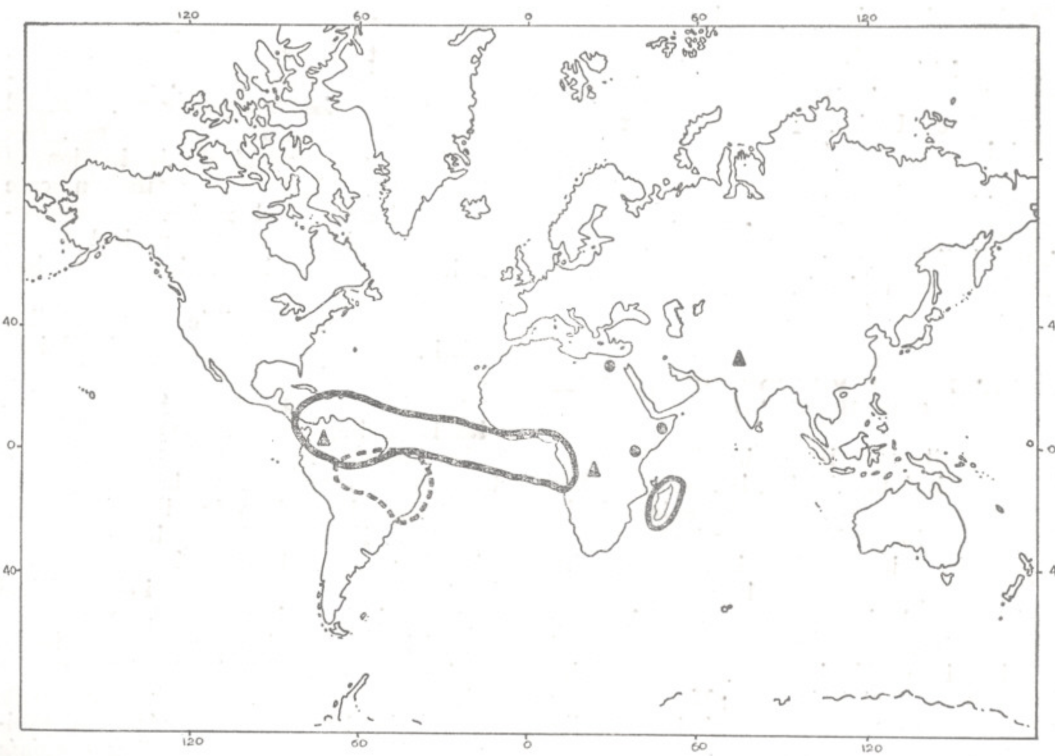
**TABLE 1 – GEOGRAPHICAL AND STRATIGRAPHICAL DISTRIBUTION OF GUTTIFEROUS FOSSIL PLANTS**

| Countries | Fossil Species | Age | | | | | | Modern Comparable Form | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Cretaceous | Eocene | Oligocene | Miocene | Pliocene | Pleistocene | Calophyllum | Mesua | Garcinia | Tavomita | Kayea | Kielmeyera | Clusia | Mammea | Platonia | Rheedia | Symphonia |
| North America | | | | | | | | | | | | | | | | | | |
| United States | 1. *Clusiaphyllum eocenicum* | — | × | — | — | — | — | — | — | — | — | — | — | × | — | — | — | — |
| Central America and West Indies | | | | | | | | | | | | | | | | | | |
| West Indies | 2. *Clusia vera* | — | — | — | — | — | × | — | — | — | — | — | — | × | — | — | — | — |
| Trinidad | 3. *Calophyllum callabaformis* | — | — | — | — | — | × | × | — | — | — | — | — | — | — | — | — | — |
| | 4. *Rheedia sylyargillacea* | — | — | — | — | — | × | — | — | — | — | — | — | — | — | — | × | — |
| | 5. *Rheedia miocenica* | — | — | — | × | — | — | — | — | — | — | — | — | — | — | — | × | — |
| Cuba | 6. *Rheedia sylyargillacea* | — | — | — | × | — | — | — | — | — | — | — | — | — | — | — | × | — |
| South America | | | | | | | | | | | | | | | | | | |
| Brazil | 7. *Calophyllum pliocenicum* | — | — | — | — | × | — | *C. calaba* | — | — | — | — | — | — | — | — | — | — |
| Colombia | 8. *Rheedia miocenica* | — | — | — | × | — | — | — | — | — | — | — | — | — | — | — | × | — |
| | 9. *Guttiferoxylon platanioides* | — | — | — | Neogene | | — | — | — | — | — | — | — | — | — | ?*Platonia* | — | — |
| | 10. *G. compactum* | — | — | — | Neogene | | — | — | — | — | — | — | — | — | — | — | — | — |
| Africa | | | | | | | | | | | | | | | | | | |
| Algeria | 11. *G. saharianum* | — | — | — | — | ?Pliocene | — | — | — | — | — | — | — | — | — | — | — | — |
| | 12. *G. barryi* | — | Palaeogene | | — | — | — | — | — | ?*Garcinia* | — | — | — | — | — | — | — | — |
| Kenya | 13. *G. symphonioides* | — | — | — | ?Miocene | — | — | — | — | — | — | — | — | — | — | — | — | ?*Symphonia* |
| Egypt | 14. *G. fareghense* | — | — | — | × | — | — | *Calophyllum* | *Mesua* | — | — | — | — | — | — | — | — | — |
| Somaliland | 15. *Symphonioxylon stefaninii* | — | — | — | — | ?Plio-Pleistocene | | — | — | — | — | — | — | — | — | — | — | × |
| | 16. *S. scec-gureensis* | — | — | — | — | ?Plio-Pleistocene | | — | — | — | — | — | — | — | — | — | — | × |
| Congo | 17. *Platoniapollinites kivuensis* | — | — | — | Neogene | | — | — | — | — | — | — | — | — | — | ?*Platonia* | — | — |
| | 18. *Garcinia* sp. | — | — | — | × | — | — | — | — | × | — | — | — | — | — | — | — | — |
| Asia | | | | | | | | | | | | | | | | | | |
| Ceylon | 19. *Mesua* sp. | — | — | — | — | — | × | | *M. ferrea* | — | — | — | — | — | — | — | — | — |
| India | 20. *Mesua tertiara* | — | × | — | — | — | — | — | *M. ferrea* | — | — | — | — | — | — | — | — | — |
| | 21. *Mesuoxylon arcotense* | — | — | — | Neogene | | — | — | *M. ferrea* | — | — | — | — | — | — | — | — | — |
| | 22. *Kayeoxylon assamicum* | — | — | — | × | — | — | — | — | — | — | *K. assamica* | — | — | — | — | — | — |
| | 23. *Indocarpa intertrappea* | — | × | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| | 24. *Garcinia borooahii* | — | × | — | — | — | — | — | — | *G. lanceaefolia* | — | — | — | — | — | — | — | — |
| | 25. *Platoniapollinites iratus* | — | × | — | — | — | — | — | — | — | — | — | — | — | — | ?*Platonia* | — | — |
| | 26. *Kielmeyerapollenites cocenicus* | — | × | — | — | — | — | — | — | — | — | — | ?*Kielmeyera* | — | — | — | — | — |
| | 27. *Calophyllumpollenites rotundus* | — | × | — | — | — | — | ?*Calophyllum inophyllum* | — | — | — | — | — | — | — | — | — | — |
| | 28. *Calophylloxylon eoinophyllum* | — | — | — | Neogene | | — | *C.inophyllum* | — | — | — | — | — | — | — | — | — | — |
| | 29. *C. indicum* | — | — | — | Neogene | | — | *C.wightianum* | | — | — | — | — | — | — | — | — | — |
| | 30. *C. cuddalorense* | — | — | — | Neogene | | — | *C.tomentosum* — | — | — | — | — | — | — | — | — | — | — |
| Sumatra | 31. *Calophyllum nathorsti* | — | — | — | — | ?Pliocene | — | — | — | — | — | — | — | — | — | — | — | — |
| | 32. *Garcinia* sp. | — | — | — | ?Miocene | — | — | — | — | × | — | — | — | — | — | — | — | — |
| Europe | | | | | | | | | | | | | | | | | | |
| Austria | 33. *Guttiferoxylon prambachense* | — | — | × | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| | 34. *G. garcinioides* | — | — | — | × | — | — | — | — | ?*Garcinia* | — | — | — | — | — | — | — | — |
| France | 35. *Mammaeites franchetis* | × | — | — | — | — | — | — | — | — | — | — | — | — | ?*Mammea* | — | — | — |
| Germany | 36. *Guttiferaephyllum moselense* | — | × | — | — | — | — | — | — | — | — | — | ?*Kielmeyera-Clusia* | | — | — | — | — |
| | 37. *Guttiferaephyllum* sp. | — | × | — | — | — | — | — | | — | — | — | — | × | — | — | — | — |
| | 38. *G. oblongum* | — | × | — | — | — | — | — | — | ?*Garcinia-Tavomita* | | — | — | | — | — | — | — |

America. Two fossil woods somewhat resembling the extant genus *Platonia* were described as *Guttiferoxylon platonioides* and *G. compactum* (Schonfeld, 1947). *Guttiferoxylon compactum* has again been described from Oligocene-Miocene and Pliocene deposits of Colombia (Mirioni, 1965), discovered in Amaga and Sineclejo-Ovejas respectively.

Leaf impressions of *Rheedia miocenica* are known from the Miocene of Trinidad, West Indies and De Mares Concession, Colombia (Berry, 1936). A species of *Rheedia* is also known from the Late Tertiary of Eastern Colombia. Another species of *Rheedia* extends into the Pliocene of Trinidad; a third in the Pliocene of Venezuela and another is found in the Pliocene of Brazil (Berry, 1945) from where *Calophyllum pliocenicum* has also been recorded (Krasser, 1903). Leaf impressions of *Rheedia sylyargillacea* are also recorded from the Miocene of Cuba (Berry, 1939).

In India, Guttiferae is also present in the Middle Tertiary. A fossil wood of *Kayea Kayeoxylon assamicum* is known from the Upper Miocene of Tipam series in Assam (Chowdhury and Tandon, 1949). From the same beds near Jaipur, a fossil wood of *Calophyllum*, *Calophylloxylon eoinophyllum* is also known in Assam (Prakash & Awasthi, 1971). This fossil closely resembles the modern wood of *Calophyllum inophyllum*. The same fossil species is also known from the Namsang beds of Mio-Pliocene age in Arunachal Pradesh (Prakash 1966) Map 5. In South India, *Calophyllum* is known from the Mio-Pliocene beds of Cuddalore series near Pondicherry. Lakhanpal and Awasthi (1965) described two species of *Calophylloxylon*, *C. indicum* and *C. cuddalorense* resembling the modern woods of *Calophyllum wightianum* and *C. tomentosum* or *C. inophyllum* respectively. Another important guttiferous genus, *Mesua* has also been recorded from the same beds. This is based on a fossil wood, *Mesuoxylon arcotense* closely comparable to *Mesua ferrea* (Lakhanpal & Awasthi, 1964), Map 5. Some woody tissues comparable to *Mesua* and *Calophyllum* are also known from Neyveli lignites (Navale, 1972). Ramanujam (1960)




Map 3 — Geographic distribution of fossil (black dot) and living (encircled area) *Symphonia* and fossil (black triangle) and living (encircled area with dotted line) *Platonia*.

has also described a *Garcinia* type of wood from the Cuddalore series and named it as *Guttiferoxylon indicum*. However, on further investigation this has been found to resemble the modern woods of *Ailanthus*. (Awasthi, Ms).

From the Neogene of South Sumatra in Indonesia, leaf impressions of *Calophyllum nathorsti* and *Garcinia* are also known (Krausel, 1929).

## QUARTERNARY

Towards the end of the Neogene, a physicochemical regime was established on the earths surface which was extremely similar to that of the present day. The resemblance included in the outlines of the continents and of the seas, the climate, orography and in the compsotion of the organic world. In fact, the processes which occurred during the Quaternary were of great importance, and before the present day geological conditions set-in, the crust passed through a series of major processes known as Quaternary glaciation.

During this period the family Guttiferae is known by the leaf impressions in West Indies. Hollick (1924) described leaf impressions of *Clusia vera* from the Pleistocene of West Indies. From the Pleistocene of Trinidad Berry (1925, 1937) also recognised the leaf impressions of *Rheedia sylyargillacea* and *Calophyllum callabaformis*.

Woods comparable to *Mesua ferrea* syn. *M. thwaitsii* are known from the Pleistocene deposits of gem pits in Sabargamuva Province of Ceylon (Chowdhury, 1964).

## CLIMATIC AND PHYTOGEOGRAPHICAL CONSIDERATIONS

The family Guttiferae is almost exclusively tropical in distribution and consists of about 40 genera and 1000 species widely distributed in both the hemispheres but common in Asia and America. No species is indigenous to the United States, but species of *Clusia*, *Calophyllum*, *Mammea*, and *Rheedia* extend from South and Central America into Mexico and West Indies (Lawrence, 1959; Willis, 1966; Hooker, 1872; Pearson & Brown, 1932). As it is generally assumed that vegetational complexes of the past had environmental requirements similar to their counterparts of today, the climatic requirements of the modern guttiferous taxa may be of great help in deciphering the palaeoenvironments, especially climate of the region, where fossil Guttiferae is known. Presence of fossil Guttiferae comparable to the seeds of *Mammea* in the Cretaceous of France and the leaf impressions resembling the leaves of the modern species of *Kielmeyera*, *Clusia*, *Tavomita* and *Garcinia* of Tropical South America and Malaysia in the Eocene of Germany and the fossil woods like those of *Garcinia* and other taxa in the Upper Oligocene and Lower Miocene of Austria would indicate a tropical to subtropical climate in that part of Europe during the Cretaceous to Lower Miocene period as against the temperate conditions prevalent there at the present time. This has been very well supported by the study of other Palaeogene angiosperm floras from Europe. The genus *Garcinia* presently occurs in the tropics of the Old World, whereas *Mammea* is mostly tropical African with a species native to the West Indies and Northern South America (Record & Hess, 1943; Chowdhury & Ghosh, 1958).

The guttiferous and other fossil leaves comparable to ferns, palms, ficus, *Laurus*, *Persea*, *Phoebe*, *Cinnamomum*, *Litsea*, *Bombax*, *Sterculia*, *Diospyros* discovered at Mosel in the Palaeogene of Germany and the contemporary geographical distribution of the analogous plants of our time indicate that the climate of this region was comparable to a rain forest of tropical South America or Malaysia during that time (Fischer, 1950).

The occurrence of fossil leaves resembling *Clusia* in the Eocene of Arkansas in United States of America would tell a different story about the past climate of that region which is having a warm temperate climate at the present day. As the genus *Clusia* with about 145 modern species of trees and shrubs, mostly epiphytic, is abundantly represented in tropical America, sparingly so in New Caledonia and Madagaskar, the climate of Arkansas was definitely tropical to subtropical during the Eocene.

In Africa the fossil records of Guttiferae are also not many (Table 1), although the family was somewhat better represented here than in Europe and America. A petrified guttiferous wood resembling *Garcinia* has recently been found near Hassi Bel Geubbour in the continental deposits of

Algeria in Central Sahara. From the same deposits near Fort Flatters, a rich vegetation has further been recorded consisting of a number of legumes and Combretaceae (Koeniguer, 1965; Louvet, 1964, 1965, 1972; Boureau, 1951a, b). The Guttiferae along with a rich variety of legumes indicate the presence of a humid forest with lot of precipitation during the Palaeogene of Algeria as against a xerophytic vegetation found there at the present time.

Another important area of the Sahara desert is Egypt where a number of plant fossils are known in the Tertiary. Some fossil woods like those of *Symphonia* and *Calophyllum* or *Mesua* were described from


MAP 4 — Geographic distribution of *Mesua ferrea*-like fossil plants (black dot) and the modern *Mesua ferrea* (stippled area).

the Miocene of Egypt. As *Calophyllum*, *Mesua* and *Symphonia* do not grow now in this part of the world, their presence during the Miocene of Egypt indicates some sort of climatic change, possibly the prevalence of aridity, after the Miocene due to which these plants became extinct. Kräusel (1939) further described a rich vegetation from Egypt during the Miocene consisting of palms, legumes, sterculias and other mesophytic taxa, which are presently common in a humid climate. It is, however, interesting to note that most of this country is a desert now with xerophytic vegetation except the valley and delta of the Nile with fertile land.

Fossil woods of *Symphonia* were also known from the ? Plio-Pleistocene of Somaliland along with a number of fossil palms, dipterocarps, legumes and sterculias (Chiarugi, 1933, p. 159). However, *Symphonia* is presently limited to Madagascar except for one species, *S. globulifera* which occurs in tropical West Africa, West Indies (Map 3), and in northern South America (Oliver, 1868; Record & Hess, 1943). Because *Symphonia* is a common tree in low humid regions, mixed with hard woods and palm forests, it became extinct from Somaliland as the desert conditions prevailed there. Somaliland is now a part of big Sahara desert mostly consisting of waste or scrubland, inhabited by nomads and all the rich, evergreen, moist loving vegetation of the past (palms, legumes, dipterocarps etc.) has disappeared from this region.

From the Tertiary of Western Rajasthan in Northern India although only a few fossil plants are so far known, they, however, represent a vegetation very different from the existing xerophytic plants of Rajasthan. The presence of fossil guttiferous leaves and fruits closely comparable to *Mesua ferrea* and *Garcinia lanceaefolia*, both evergreen taxa (Lakhanpal, 1964), in the Middle Eocene of Kapurdi in Western Rajasthan, indicate a much higher rainfall and a moist climate in this region during the Eocene times in contrast to desert conditions with a poor type of scrub forest found today. Since the area comprising of eastern Bengal and Upper Burma is most suitable for a natural growth of *Mesua ferrea*, *Garcinia* and some other Guttiferae at the present time, it may seem probable that conditions similar to these existed in Rajasthan during the Eocene period when *Mesua ferrea* and other Guttiferae flourished in that area.

The existence of an evergreen, moist loving forest flora in the Eocene of Rajasthan is further supported by the discovery of pollen grains resembling those of *Calophyllum inophyllum*, *Platonia* and *Kielmeyera* from the Palana lignites (Sah & Kar, 1974). All these are evergreen taxa of Guttiferae and it is interesting to note that both *Platonia* (Map 3) and *Kielmeyera* are presently confined to tropical South America, mostly in Brazil. If the identification of these two forms is confirmed, this would further substantiate the presence of tropical American elements in the Intertrappean flora of the Deccan. *Cyclanthodendron* compared to the tropical American genera *Cyclanthus* and *Carludovica*, and *Simarouboxylon* identified with the genus *Simarouba* of Brazil, Venezuela, British Guiana and Cuba are known from the Early Eocene beds of the Deccan Intertrappean series. *Rodeites*, a hydropteridean sporocarp, also from the Intertrappean beds, has further been compared with *Regnellidium*, a water fern of Brazil. All these forms may provide a link between the Eocene flora of the Deccan and Rajasthan and the modern flora of tropical South America. Although their origin in the Indian flora is quite obscure, it seems likely that these groups, once enjoying a wider and greater distribution in the tropics, seem to have been strongly reduced at the present time. However, the occurrence of South American tropical elements during the Eocene of India is quite enigmatic and needs a detailed reinvestigation and comparison with the modern plants so as to get a true picture of their systematic position.

In South India the presence of fossil Guttiferae comparable to *Mesua ferrea*, *Calophyllum wightianum*, *C. tomentosum* and *C. inophyllum* along with a variety of other fossil forms around Pondicherry on the east coast during the Cuddalore times and their absence in that region at the present day indicates a somewhat different climate there during the Mio-Pliocene times. These species (Maps 4, 5) along with a number of other modern comparable forms of the fossil flora at Pondicherry are presently growing in the evergreen forests of the Western Ghats in South Malabar and also


MAP 5 — Geographic distribution of *Calophyllum inophyllum* — like fossil plants (black dot) and the modern *Calophyllum inophyllum* (stippled area).

further South near Tinnevelly, where there is more atmospheric precipitation than on the eastern coast. This indicates that similar vegetation was also present near Pondicherry during the Mio-Pliocene times which died out from there due to further desiccation indicating thereby that the eastern coast of South India has become drier since the Cuddalore times. This has also been amply supported by the extinction of *Dipterocarpus*, *Dryobalanops* and *Anisoptera* from near Pondicherry. These were present there during the Cuddalore times (Awasthi, 1971, 1972; Navale, 1963). *Mesua ferrea* is common in Tropical Asia and in the Indian region (Map 4) it is presently found in the evergreen forests of Western Duars, Assam, Chittagong, Upper Burma, Tenasserim, Andaman Islands, Western ghats from North Kanara southwards to Tinnevelly and in Ceylon, whereas *Calophyllum wightianum* and *C. tomentosum* grow in evergreen forests of Western ghats from North Kanara to Travancore (Gamble, 1902; Pearson & Brown, 1932; Maheshwari, 1963).

Thus it is apparent from the geological records that the family Guttiferae was once more widely spread than the present day and was known even from Europe and Central United States which are presently devoid of guttiferous plants. This is because of a change in climate of these regions due to which the guttiferous taxa moved down to more favourable warmer conditions.

## REFERENCES


AWASTHI, N. (1971). Revision of some dipterocarpaceous woods previously described from the Tertiary of South India. *Palaeobotanist.* **18**(3): 226-233, 1969.

Idem (1972). Occurrence of some new dipterocarpaceous woods in the Cuddalore series of South India. *Palaeobotanist.* (in press).

Idem (M.S.). Revision of some dicotyledonous woods from the Tertiary of South India.

Bancroft, H. (1932). Some fossil dicotyledonous woods from the Miocene beds of East Africa. *Ann. Bot.* **46**(184): 745-767.

BERRY, E. W. (1925). A Pleistocene flora from the island of Trinidad. *Proc. U.S. natn. Mus.* **66**: 1-9.

Idem (1930). Revision of the Lower Eocene Wilcox flora of south eastern States, with description of new species, chiefly from Tennessee and Kentucky. *U.S. geol. Surv. Prof. Pap.* **156**: 113.

Idem (1936). Miocene plants from Colombia, South America. *Bull. Torrey bot. Club.* **63**(2): 53-66.

Idem (1937). A Late Tertiary flora from Trinidad B.W.I. *John Hopkins Univ. Stud. Geol.* **12**: 69-79.

Idem (1939). A Miocene flora from the gorge of the Yumari river, Matansas, Cuba. *Ibid.* **13**: 95-135.

Idem (1945). Late Tertiary fossil plants from eastern Colombia. *Ibid.* **14**: 171-186.

BOUREAU, ED. (1951a). Etude paleoxylologique du sahara (XIV). *Leguminoxylon menchikoffii* n. sp. bois eocene decouvert au Nord-Ouest de Fort-Flatters (Algeria). *Bull. Mus. natn. 2e serie.* **23**(3): 331-338.

Idem (1951b). Etude Paleoxylologique du Sahara (XV). Sur un nouveau bois mineralise, *Euphorbioxylon lefrancii* n. sp., recolte en Algerie, au nord-ouest de Fort-Flatters. *Ibid.* **23**(6): 706-712.

Idem (1952). Etude Paleoxylologique du Sahara (XVII): *Guttiferoxylon saharianum* n. sp., bois neogene silicifie de Bekati el Bass (confins Algero Soudanais). *Ibid.* **24**(6): 594-600.

CHIARUGI, A. (1933). Fossil del Pliocene e del Pleistocene. 4. Legni Fossili della Somalia Italiana. *Palaeontographica Italica.* **32**(1): 96-167.

CHOWDHURY, K. A. (1965). Wood remains from gem pits of Sabaragamuva Province of Ceylon. *Spolia Zeylanica.* **30**(2): 3-6.

CHOWDHURY, K. A. & GHOSH, S. S. (1958). Indian Woods 1. *Dehra Dun.*

CHOWDHURY, K. A. & TANDON, K. N. (1949). *Kayeoxylon assamicum*, gen. et sp. nov. a fossil dicotyledonous wood from Assam. *Proc. natn. Inst. Sci. India.* **15**(2): 59-65.

DELTEIL-DESNEUX, F. (1970). Sur un echantillon de bois fossile du Tertiaire d' Algerie. *Guttiferoxylon barryi* n. sp. 92*e Congres natn. Soc. Savantes Strasbourg et Colmar.* **3**: 153-161.

FISCHER, E. (1950). Pflanzenabdrucke aus dem Alttertiar von Mosel bei Zwickau in Sachsen. *Abh. Geol. Dienst. Berlin* N.F. **221**: 3-28.

FLICHE, P. (1896). Etude sur la fossile de l Argonne Albien-Cenomanien. *Soc. Sci. Nancy Bull.* Ser. E **14**: 114-306.

GAMBLE, J. S. (1902). A manual of Indian Timbers. *London.*

HOFMANN, E. (1944). Pflanzenreste aus dem Phosphoritvorkommen von Prambachkirchen in Oberdonau. *Palaeontographica.* **88B**: 1-86.

Idem (1952). Pflanzenreste aus dem Phosphoritvorkommen von Prambachkirchen in Oberosterreich. II. *Ibid.* **92B**: 122-183.

HOLLICK, A. (1924). A review of the fossil flora of the West Indies, with description of new species. *N.Y. Botan. Gard. Bull.* **12**: 259-323.

HOOKER, J. D. (1872). Flora of British India Part I. *London.*

JAIN, R. K. (1964). *Indocarpa intertrappea*, gen. et sp. nov., a new dicotyledonous fruit from the Deccan Intertrappean series, India. *Bot. Gaz.* **125**(1): 26-33.

KOENIGUER, J. (1965). Sur un bois fossile du continental terminal du Tinrhert (Sahara Central) *Leguminoxylon schenkii* n. sp. 90*e Congres des Soc. Savantes, Nice.* **2**: 333-345.

KRASSER, F. (1903). Konstantin von Ettingshausen's studien uber die fossile flora von Ouricanga in Brasilien. *Sitzungs. K. AK. Wissen. Wien math. natu. Kl.* **112**(1): 1-9.

KRAUSEL, R. (1929). Fossile Pflanzen aus dem Tertiar von Sud-Sumatra. *Verhand. geol. Mynb. Gen. Voor Ned. Kol. Geol. Ser.* **9**(11): 1-44.

Idem (1939). Ergebnisse der Forschungreisen Prof. E. Stromers in den Wusten Agyptens. IV. Die fossilen floren Agyptens. *Abh. Bayer. Akad. Wissen. math-natur.* N.F. **47**: 5-140.

LAKHANPAL, R. N. (1964). Specific identification of the guttiferous leaves from the Tertiary of Rajasthan. *Palaeobotanist.* **12**(3): 265-266, 1963.

Idem (1966). Some Middle Tertiary plant remains from South Kivu, Congo. *Ann. Mus. R. Afr.*

*Cent. Tervuren, Belge. Ser.* 8, *geol. Sci.* **52**: 21-30.

LAKHANPAL, R. N. & AWASTHI, N. (1964). *Mesuoxylon arcotense* gen et sp. nov. a fossil dicot wood from the Tertiary of South Arcot District, Madras, India. *Palaeobotanist.* **12**(3): 260-264, 1963.

Idem (1965). Fossil woods of *Calophyllum* from the Tertiary of South India. *Ibid.* **13**(3): 328-336, 1964.

LAKHANPAL, R. N. & BOSE, M. N. (1951). Some Tertiary leaves and fruits of the Guttiferae from Rajasthan. *J. Indian bot. Soc.* **30**(1-4): 132-136.

LAWRENCE, G. H. M. (1959). Taxonomy of vascular plants. *New York.*

LOUVET, P. (1964). Sur une combretaceae fossile nouvelle du Tinrhert (Algerie). 89*e Congres des Societes Savantes, Nice.* 281-301.

Idem (1965). Sur une nouvelle Legumineuse fossile du Tinrhert, *Afzelioxylon kiliani* n. gen. n. sp. *Ibid.* **2**: 317-332.

dem (1972). Sur deux Legumineuses fossile OUVET, du Tinrhert (Algeria). *Ibid.* **3**: 23-37.

MAHESHWARI, J. K. (1963). Taxonomic studies on Indian Guttiferae. II. The genus *Mesua Bull. bot. Surv. India.* **5**(3 & 4): 335-343.

MIRIONI, H. (1965). Etude anatomique de quelques bois Tertiaries de Colombie. *Bol. de Geol. univer. Ind. d Santander.* **20**: 27-59.

NAVALE, G. K. B. (1963). Some silicified dipterocarpaceous woods from Tertiary beds of the Cuddalore series near Pondicherry, India. *Palaeobotanist.* **11**(1 & 2): 66-81, 1962.

Idem (1972). Some contributions to the palaeobotany of Neyveli Lignite, South India. *Ibid.* **20** (2): 179-189.

OLIVER, D. (1868). Flora of Tropical Africa. Vol. I. *Kent.*

PEARSON, R. S. & BROWN, H. P. (1932). Commercial timbers of India. *Calcutta.*

PRAKASH, U. (1966). Some fossil dicotyledonous woods from the Tertiary of Eastern India. *Palaeobotanist.* **14**(1-3): 223-235, 1965.

PRAKASH, U. & AWASTHI, N. (1971). Fossil woods from the Tertiary of Eastern India, II. *Ibid.* **18**(3): 219-225, 1969.

RAMANUJAM, C. G. K. (1960). Silicified woods from the Tertiary rocks of South India. *Palaeontographica.* **146B**: 99-140.

RECORD, S. J. & HESS, R. W. (1943). Timbers of the New World. *New Haven.*

SAH, S. C. D. (1967). Palynology of an Upper Neogene profile from Rusizi valley (Burundi). *Annls. Mus. r. Afr. Cent. Ser.* 8. **57**: 1-173.

SAH, S. C. D. & KAR, R. K. (1974). Palynology of the Tertiary sediments of Palana, Rajasthan. *Palaeobotanist.* **21** (2) 163-188

SCHÖNFELD, G. (1947). Holzer aus dem Tertiar von Kolubien. *Abh. Sencken. naturf. gesells.* **475**: 4-48.

SHALLOM, L. J. (1963). Fossil dicotyledonous wood of the family Guttiferae from the Deccan Intertrappean beds of Mahurzari. *Proc.* 50*th Indian Sci. Congr., Delhi.* **3**: 397-398.

STRAKHOV, N. M. (1962). Principles of Historical Geology. Parts 1 & 2. *Jerusalem.* (Translated from Russian).

WILLIS, J. C. (1966). A dictionary of the flowering plants and ferns. *Cambridge.*