Fossils in amber

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AMBER is a fossilized tree resin that occurs in various parts of the world and ranges from about 4 million to 300 million years of age. The location of amber deposits depends on the presence of past forests containing resin-bearing trees. But not any resin-bearing trees – only those trees containing certain types of resin: resin that is resistant to decay, that can readily polymerize and that is not subjected to the destroying thermochemical and shear forces in the earth's crust. Such resins are not common, and contrary to popular belief, resins from our most common coniferous trees today (i.e. pines, spruces, firs) never withstood the tests of time and ended up as amber.

During the stages of amberization, the events which occur when resin turns into amber, the material passes through an intermediate stage called copal. Copal is young amber that does not yet possess the physical properties of amber, (i.e. hardness, solubility, melting point) yet has the potential of becoming amber after a few million years. Copal deposits occur around the world and because the melting point of copal is lower than that of amber (under 150°C, whereas that of amber ranges from 200 to 380°C) much copal is melted down to make varnishes and other commercial products.

Amber and copal deposits are fascinating to the scientist because of the types of life forms that are included inside them. As seen in Table 1, a range of plant and animal life occurs in several major amber-bearing deposits in the world. Some of the various life forms in Dominican amber are illustrated in the present work. These include terrestrial isopods (Crustacea) (Figure 1), various flies (Diptera) (Figure 2) as well as ground beetles (Carabidae, Coleoptera) and centipedes (Scolopendridae, Chilopoda) (Figure 3). Other types of insects include leaf beetles (Chrysomelidae, Coleoptera) (Figure 4) and moths (Tortricidae, Lepidoptera) (Figure 5). Spiders (Araneae, Arachnida) (Figure 6) are fairly common whereas snails (Gastropoda) (Figure 7) are quite rare. Plant parts in a recognizable state are scarce but do occur as is shown by the *Mimosa* or *Acacia* leaf in Figure 8. These categories consist of microbes, which include bacteria, actinomycetes, fungi and protozoa; plants, including moss and liverworts, ferns, gymnosperms and angiosperms; invertebrates, including not only insects but also arachnids, terrestrial crustacea, myriapods, nematodes, mollusca; and lastly vertebrates or their remains. This latter category is the rarest and the most costly – prices for vertebrates ranging in the tens of thousands of dollars. In amber can be found entire frogs and lizards, feathers of birds and hair of mammals. A more complete synopsis of life forms in amber is presented in my book *Life in Amber*[1].

Of the many interesting topics of study with amber inclusions, I would like to further discuss the following: (i) How amber fossils can assist us in reconstructing ancient environments, (ii) how amber fossils can help us understand distributional patterns of animals and plants, (iii) what amber can tell us of ancient symbiotic associations (*Paleosymbiosis*) and (iv) how amber fossils can furnish us with genetic information of past organisms. In conclusion, a few words are added regarding amber fakes and fossilized resin in India.

Table 1. Major deposits of amber with ages, location and general categories of inclusions (modified from Poinar *et al*[9])

Deposits	Location	Age (in millions of years)	Categories of inclusions
Mexican	Southern Mexico	22–26	Microbes Plants Invertebrates Vertebrates
Dominican	Northern Europe	25–40	Microbes Plants Invertebrates Vertebrates
Baltic	Northern Europe	40	Microbes Plants Invertebrates Vertebrates
Canadian	Manitoba, Alberta	70–80	Plants Invertebrates
Middle East (Lebanese)	Lebanon, Israel, Jordan	120–135	Plants Invertebrates

Reconstructing ancient environments

Amber abounds with clues of the plants and animals that lived in the ancient forest. What is needed are people with the knowledge to decipher these clues, essential to identify the source. As an example, we have found halictid bees in Dominican amber. Associated with these bees are elongate pollen grains that obviously came from one of the last plants the bee visited. A palynologist was able to identify the pollen as belonging to a palm. Thus, from this one small piece of amber we know that halictid bees and palm trees existed some 25–40 million years ago in a now vanished

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Figure 1. Pillbug in Dominican amer.

Figure 4. Leaf beetle in Dominican amber.

Figure 2. Fly in Dominican amber.

Figure 5. Moth in Dominican amber.

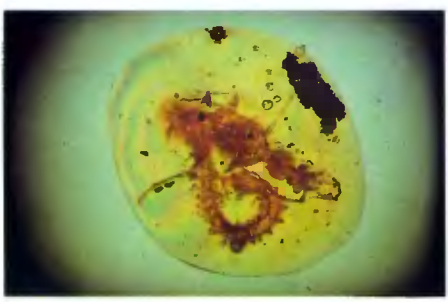

Figure 3. Beetle and centipede in Dominican amber.

Figure 6. Spider in Dominican amber.

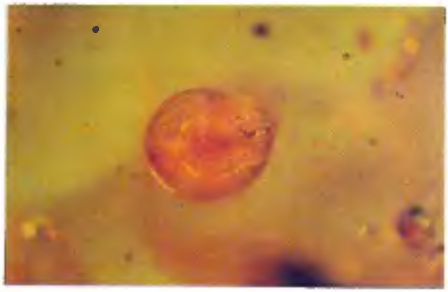

Figure 7. Snail in Dominican amber

Figure 8. Mimosa leaf in Dominican amber

forest and we know something about the behaviour of that extinct bee. A second example involves a grass floret and a vertebrate predator. We discovered a floret of a particular genus of bamboo (*Pharus* sp.) in a piece of Dominican amber. The tip of the floret was covered with minute hooks that function to attach the seed to the fur or feathers of vertebrates for dispersal.

Still running through the hooks were strands of mammalian hair. A microscopic examination of the hair showed it to belong to a carnivore, possibly a large cat since modern day *Pharus* seeds have been found on jaguars in Panama. Thus we not only found the presence of a bamboo and carnivore in that piece of amber, but evidence of ancient behaviour. By putting together each little piece of evidence, we can arrive at a broader picture and begin to reconstruct the landscape and climate. Basic to such a reconstruction lies the principle of uniformity, which means that since behaviour of related organisms tends to be constant, we can suppose that the behaviour of extinct organisms was basically the same as their closely related extant descendants today. This is substantiated by Boucots analysis of behaviour in the fossil record[2].

Amber and distributional patterns

By comparing fossils in amber with their closest relative today, we can learn about past distributional patterns of plant and animal genera. For instance, Hennig[3] described an acrocerid fly in Baltic amber (*Prophilopota succinea* Hennig) whose living relatives today extend down into northern India. The tree that is responsible for the production of much of the Dominican amber is the legume, *Hymenaea protera*[4]. Both morphological and DNA studies show that the closest relative of this extinct species occurs in East Africa[5]. The presence of *Leptomyrmex neotropicus* Baroni Urbani in Dominican amber was exciting since this genus of ants is today restricted to the Australian region. These examples not only suggest a much larger distribution in the past of certain genera of plants and insects, but they provide supporting evidence and information regarding the time and place of continental plate movements.

Amber and paleosymbiosis

Amber is certainly one of the best media for recording ancient relationships. This is because death comes quickly and gently in amber. The organisms must expire almost immediately after being submerged in the sticky resin. There is little struggle by the organism, although internal parasites often have a few additional moments of life, often just enough to force their way out of the host, and then they also perish. Such a rapid and non-traumatic method of expiration is conducive to recording symbiotic and parasitic associations. Thus, there are parasitic roundworms caught in their attempts to leave their insect hosts, there are blood-sucking mites with their mouthparts still attached to the hosts' integument; there are pseudoscorpions still holding on to the elytra of beetles that were transporting them to new habitats before falling into the resin. The recording of such associations is rare, even in amber, but they give us our best records of fossil symbiotic associations.

Amber and genetic information of the past

Amber not only preserves the external form of microbes, plants, invertebrates and vertebrates in exquisite detail, but it also is highly unusual in preserving tissue and even DNA of embedded organisms. Over 10 years ago, we discovered that cells, cell organelles, nuclei and chromatin were still present in a fossilized fly in Baltic amber after 40 million years[6]. This amazing discovery made us wonder whether DNA might also be preserved

after such a long period. In 1992, we showed that DNA was preserved in amber insects, and the first case was a bee preserved in amber from the Dominican Republic[7, 8]. Since then DNA has been extracted from other amber insects and a plant in amber[9]. The discovery of DNA in a weevil in Lebanese amber[10] and a leaf in Dominican amber[5] presently hold the record for the oldest animal and plant DNA. Much speculation has occurred regarding the properties of resins and amber which might be responsible for this remarkable degree of preservation. A rapid withdrawal of moisture from the tissue immediately after immersion in the resin coupled with the natural fixation of the tissue with plant compounds probably accounts in large part for the high degree of preservation. It now appears that organisms in amber represent the best preserved tissue ever known in the fossil record. The door is wide open for a host of evolutionary and phylogenetic studies involving fossils in amber and even copal.

Fake amber

Because of the recent increase in value of amber with fossils, there has been a corresponding increase in the number of amber fakes appearing on the market. Fakes usually fall in three general categories: (i) recent organisms placed in plastic, (ii) recent organisms placed in copal and offered as amber, and (iii) recent organisms placed in authentic amber. Fakes belonging to the first two categories are encountered more frequently than those of the latter.

Methods to determine amber fakes have been presented earlier[11] and they can be used to detect the majority of forgeries.

Amber and copal in India

India contains several plants which produce hardened resin or copal for various commercial purposes. One of these is a large ratton palm (*Daemonorops draco*) producing deep red resin which when produced and dissolved in alcohol yields a red dye called 'Dragon's Blood'. It is principally used as a red stain or spirit varnish. The second commercial resin from India is 'Mastic' which originates from the Pistachio tree (*Pistcia lentiscus*). The resin is opaque yellowish to yellow-green in colour and is used both in spirit varnishes and for lithographic works[12].

According to Moldenke and Moldenke[13] India was also the source of frankincense (*Boswellia thurifera*) since Biblical times and the finest frankincense imported to the lands of Asia Minor came from India and the islands of the Indian Archipelago, usually through Arabia. The related species *B serrata*, which grows on dry hills in India, also produces a commercially important resin.

There are records of gum arabic harvested from trees in South India. It is apparently used in tie dying as an adhesive for the dye. Further information on the use of resin by the Indian people can be found in the book (in Marathi) by Desai Vaman Ganesh entitled '*Oushdi Sangrha*'.

Records of Indian amber exist in the works of Pliny the Elder (Natural History, 1st Century AD). He records that Archelaus, who reigned over Cappodocia, claims that amber was brought back from India in a rough state, with fine bark still adhering to it. It was polished by boiling it in the fat of a suckling pig. This may have been amber, however, nobody has located or recorded any actual amber mines in India. So, either these early reports dealt with amber coming into India from another area, such as the Baltic, the location of the Indian amber sites has been lost in obscurity or the material was not really amber, but more likely copal. In fact there are early reports that African copal from Zanzibar was shipped to India for the production of varnish.

Support for the shipment of Baltic amber in India comes from Fraquet[14] who states that Baltic amber was sold in India back in the sixteenth century. The same author also claims that in 1874, Baltic amber pieces were used in India to ornament pipes, arms saddles and bridles.

According to Sen Gupta (personal communication, September 13, 1983) people of the Santhal tribe in Bengal wear amber. In addition, many herders place amber necklaces around their cows' necks in order to protect them from mishaps. There is no doubt in my mind that somewhere in the earth that makes up India, there is amber, probably with fossils. But it may be buried very deeply and be difficult to discover. That only the future can tell.

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