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BALTIC AMBER INCLUSIONS AND THEIR INVESTIGATIONS IN LITHUANIA

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Summary

Inclusions help in investigations of many biological, zoogeographical and palaeoecological questions. The inclusion is not the hollow space in the amber. It is possible to find preserved tissues there. The true colors of the inclusions are not preserved, but pigmented spots on the wings and body sclerites are preserved. Most inclusions are found in the clear flaky amber. Such amber formated, when liquid resins constantly soaked from the tree wounds. Insects are the most abundant group of all inclusions (86-92%), the second group are arachnids (7.5-13%), animals of other groups form only 0.1-1.7%; plant inclusions are very rare – only 0.4%.

Differences between recent and "amber" forest's fauna usually are at the genus level, but species, which were active during formation of amber are never met today.

The Palanga Amber Museum has one of the biggest collections of fossiliferous amber in the world (14 478 pieces), when Kaliningrad Amber Museum's collection is rather small (1 200 pieces).

The complex of crane flies found in the Baltic amber (150 species) is related to the recent Holarctic fauna.

Formation of amber inclusions

The complex of plant and animal inclusions, which are found in the amber, is tied with the growing conditions and distribution area of the amber trees. Probably that was not uniform biotope, but was like a complex of different ecological conditions, because there are samples of animals and plants found in amber, tied with forests, swamps, bogs, meadows, mountains, lakes, rivers and other. Investigations of amber inclusions help in evaluation of climatic, geographical and other conditions of Eocenian/Oligocenian period. Evolutionary conformities of separate animal and plant groups during Cenozoic Era are found because of amber inclusions too. Ancestral and close to them forms of many recent groups are found in amber too. Inclusions help in investigations of many biological, zoogeographical and palaeoecological questions.

Inclusions are known not only from Baltic amber. They are also found in nearly 30 different kinds of fossil resins with different ages. Inclusions are absent only in those fossil resins, which occurred during formation of brown coal, and also in those, which were produced in very small quantities (Katinas, 1983). The small drops of resin do not covered whole entrapped organism, and, due to contact with atmosphere, it sooner or later disintegrated. Because of that, abundance and diversity of inclusions in amber and other kinds of resins mostly depends not on faunal and floral abundance and diversity of that period, but, first of all, on the amount of produced resin.

Usually plants and animals were entrapped into the resin by the accident: they were blowed by the wind, soaked into the liquid resins, resin drops slumped on them and similar. There are many volatile terpenes in the resin, which usually intimidate insects and other invertebrates. Most of insects, entrapped in amber, were alive. Only some of them were already dead, dried out, teared by predators. Insects, entrapped into the resin, died very quickly. Many of them are very well preserved, even smallest details of their structure are seen: hairs, pubescence or scales. Even such delicate structures as pubescent antennae of midges (Chironomidae) are not sticked together in the amber. That means, that secreted resins were very liquid, and hardened rather quickly in the open air. Such delicate structures as wings and antennae would be strongly deformed, if insects were entrapped in rather viscose medium. On the other hand, such fragile and easy breakable structures as legs of crane flies, often are found broken and scattered nearby the insect in the same amber block. This could be because of flowing resins which broke these legs, or that was a result of insects efforts to escape.

Insects and other small invertebrates were preserved rather well in the resin, but bigger and softer parts of them decomposed from inside and resulting gases were spread outside. They look like white dust or white clouds around the body in the amber. Mostly such white clouds are found around softest parts of inclusion like intersegmental membranes, or close to its natural openings like mouth, anus and spiracles. Such white exudes are covering taxonomically important features of the specimen and usually it is very difficult or totally impossible to see them. Sometimes it is possible to clarify them by careful heating of amber piece under pressure or by autoclaving.

The inclusion is not the hollow space in the amber having ideally preserved shape of the insect or other organism. It is often possible to find preserved tissues or separate more chitinized structures there. The true colors of the inclusions are not preserved and all specimens have different shades of brown, but pigmented spots on the wings and body sclerites are preserved – all specimens of the same species have the same wing pattern.

Most inclusions are found in the clear flaky amber. Such amber formatted, when liquid resins constantly soaked from the tree wounds. Insects or plant fragments were caught into the older resin and newly exuded layer covered them on the top. That's why most inclusions are found in the flaky amber, and are very scarce in the solid and especially unclear amber pieces. If new layer of resin was exuded after longer period, entrapped insect or other creature usually was hurt by bigger animals or mould grows.

Flaky amber forms 8-15 % of all amber deposits. Inclusions are found in 41-87% pieces of flaky amber according to different authors (Katinas, 1983; Klebs, 1887), but I would say, that these numbers are much lower in reality. Amount of inclusions strongly differs in separate deposits and in different places of the same deposit. That is possibly tied with that, from where this amber was carried out by the water – from forests or from their margins.

Insects are the most abundant of all inclusions (86-92%), the second group are arachnids (7.5-13%), animals of other groups form only 0.1-1.7%; plant inclusions are very rare – only 0.4% (according to the collections of different museums). Amber with tree bark and pubescence of oak buds, which are found in most flaky amber pieces are not counted. Systematic position of inclusions found in all Baltic amber localities is very similar, but proportions of separate systematic groups in different collections are very diverse. That's because usually not all inclusions, found in the amber, are accumulated in museums, but preferred are separate, more rarely found or impressive groups, or it depends on specialists of separate systematic groups working in the museum during the accumulation of the collections.

Systematic composition of inclusions do not show real relationship of separate groups of organisms, which existed in the "amber" forest, because many factors influenced preservation of them in the resin. The main factor was size of an organism. The best preserved are the smallest organisms and their parts. Bigger animals had enough strength to escape. If they died in the amber, usually some parts of them were not totally covered by the resin, and other animals or fungi damaged them. Usually bigger organisms disintegrated from inside. Even in the cases, when bigger organisms were totally covered by the resin, later, during geological processes, some parts of them because of amber oxidation, or due to rubbing with the surrounding substrate, became exposed to the atmosphere and disintegrated. Usually only forest insects had possibilities to fall into the resin. Water organisms and insects from open localities are very rare. They were caught by the resins only randomly.

Usually these organisms, which were active during the driest season of the year, or were living in the driest places are not found in the amber. That's because resins were exuded only in spring and insects, flying during the other seasons had no chances to be caught by them.

Differences between recent and "amber" forest's fauna are nor very big at the family or even genus level, but species, which were active at those geological times are never met today. It is not very difficult to find similarities between "amber" and recent fauna, because geologically amber is not very old – only about 40 million years (Poinar, 1992). Most evolutionary changes of faunal elements were very slight during that period, even smaller changes were in their ecological preferences.

The value of amber inclusions and main collections

Amber has always been admired and valued for its beauty as a gem. The value of amber, however, depends on whether it is being appraised for public or scientific purposes. The public desires a piece of beautiful color, polish, and form, whereas the biologist looks for an interesting inclusion that can be clearly seen and examined. The greatest commercial value of amber, for both the public and scientists, comes from the inclusions it contains. From the biological standpoint, the value of fossiliferous amber depends on the following (according to Poinar, 1992):

1. The rarity of the inclusion. Most ants and fungus gnats are fairly common in amber, and such common inclusions are not as valuable as such rare ones as a flea or tick. Well-preserved vertebrates, such as lizards and unusual arthropods like scorpions have values tens of thousands times higher, than ants and fungus gnats.

2. The state of the inclusion's preservation. The value, from both a scientific and aesthetic point of view, is increased when a specimen is well preserved (in life-like form). Frequently, a specimen will be partially disintegrated from microbial activity, obstructed by milky deposits or mold, or "washed out" from other causes. Fossils that are complete and can be identified are more valuable than those that are incomplete and cannot.

3. The clarity of amber. Cloudy amber usually obstructs the examination of inclusions, and air bubbles and other deposits including organic debris may block the fossil from clear view. Sometimes the obstruction can be ground away but this always involves the risk of damaging the specimen.

4. The position of the inclusion. A specimen positioned along the longitudinal axis of an oval piece of amber is more easily seen than one positioned perpendicular to the axis (sometimes the amber can be reshaped if fractures are not extensive). Some insects are rolled up ventrally or wrapped around themselves, making identification difficult.

5. The size of the inclusion. Anything large enough to be distinctly seen without the aid of a hand lens will be appealing to the public, but most insects enclosed in amber are small (less than 5 mm long). From the scientific standpoint, size is important only in its relation to the rarity of the inclusion. Because large insects in amber are generally uncommon, species of large insects may be rare; species of small insects can be just as rare, however.

Unfortunately for biologists, fossiliferous amber does have popular appeal, and many rare fossils in amber bring high prices from private collectors, thus eliminating them from study by scientists. For this reason, the acquisition of fossiliferous amber by various institutions should be encouraged. Most natural history museums contain small collections of fossiliferous amber.

The assembly of many collections, biological and otherwise, deposited in museums throughout the world, often stems from the energy and finances of nonprofessionals, whose enthusiasm and finances often allow them to gradually amass large collections. Almost all of the significant collections of fossiliferous amber that have been deposited in museums throughout the world and studied by experts have been amassed by amateurs, many of whom were or are involved commercially in the sale of amber.

Undoubtedly the largest assemble of amber was the famous Stantien and Becker collection of Baltic amber originally held at the Königsberg University Geological Institute Museum in Samland (Klebs, 1910). This collection included some 120 000 animal and plant fossils that had been gathered during the extensive amber mining operations by Wilhelm Stantien, an innkeeper in Memel, and merchant Moritz Becker. This venture started in 1860 (Ley, 1951). Over the years, their collection of Baltic amber provided the great majority of specimens used throughout the world for scientific study. It was feared that during the Second World War the entire collection had been destroyed by bombing (Wenzel, 1953); however, it was later learned that before the bombing, the collection had been divided and deposited in various localities, with the result that at least a portion of it was saved. Many private collections of Baltic amber were either sold or lost during the war.

The biggest collections of Baltic amber are:

British Museum of Natural History, London	25 000 pieces
Museum of the Earth, Warsaw	25 000 pieces
Zoological Institute, St. Petersburg	25 000 pieces
Paleontology Museum, Humboldt University, Berlin	20 000 pieces
Museum of Comparative Zoology, Harvard University, Cambridge	16 000 pieces
The Amber Museum, Palanga	14 478 pieces

Institute for Geology and Paleontology, Göttingen	11 000 pieces
Zoological Museum, Copenhagen	7 600 pieces

About two thirds of world amber reserves are located on the Russian territory, nearly Jantarny village, Kaliningrad region, but there are only about 1 200 units in the Kaliningrad Amber Museum's collection. This collection was created, mainly, according to a principle of outward attractiveness, and serves as a basis for creating expositions only (Ezhova, 1995). Any scientific investigations of that collection are forbidden.

Recent investigations of amber inclusions in Lithuania

The more intensive studies of Baltic amber inclusions are not carried out in Lithuania now. That could be explained by the bad financial situation of scientific institutions throughout the country, but, first of all, I would say, it depends on the interests of the scientists themselves. The only systematic works on amber inclusions in Lithuania are those of dr. E. Budrys (1993), where he describes new species of digger wasps (Hymenoptera, Sphecidae), and few publications by the author, which were done just during the few last years. They are assigned for the nematoceran flies (Diptera, Nematocera) of Baltic, Dominican and Jordanian amber (Podenas, 1997; 1999a; 1999b; 1999c; 1999d; 2000a; 2000b; Podenas, Poinar, 1999).

Crane flies in the Baltic amber (Diptera, Tipulomorpha)

Crane flies (Diptera: Cylindrotomidae, Limoniidae, Pediciidae, Tipulidae and Trichoceridae) form only about 0.36% of all inclusions, which are seen with naked eye (we are not counting plant pubescence, which are found in most flaky amber pieces) (this number is get by the author during the expertises of all amber with inclusions, which are carried abroad from Lithuania through the customs, during the calculations in the Department of Cultural Heritage, Ministry of Culture of Lithuania). There are just slightly more than 2% of pieces with crane flies in Palanga Amber museum's collections. More than 80% of all crane flies belong to 2-3 commonest species *Cheilotrichia minuta* Meunier, 1899, *Trichoneura vulgaris* Loew, 1850 and somewhat rarer *Rhabdomastix pulcherrima* Meunier, 1906. The other rarer species form the rest part.

The complex of crane flies found in the Baltic amber, without doubt, is related to the recent Holarctic fauna. 50% of genera of crane flies from Baltic amber have Holarctic distribution now; additionally more than 15% of genera are found in Holarctic and Ethiopic regions; about 8% of genera are found only in Palaearctic; 23% of genera are found throughout the world (cosmopolitic distribution) and only less than 4% belong to genera with Neotropical distribution. So more than 95% of all genera found in the Baltic amber are "one's own". Together there are paleotropical elements too – these are genera *Styringomyia*, *Toxorrhina* and *Trentepohlia*. Alone species from those genera were described in the middle of 19th and beginning of 20th centuries. But there exist a possibility, that these species were described not from the Baltic, but from Dominican amber. Most of the collections, which were accumulated in the Königsberg and in the museums of Germany before the Second World War, disappeared, and to check these amber pieces and their origin is impossible now. We had the possibility to check tens of thousands of Baltic amber pieces with crane flies only, but we found no one, even badly preserved specimen, belonging to these genera. On the other hand, crane flies, belonging to these genera are very common in Dominican amber (Podenas, Poinar, 1999). Similar situation is with the genus *Macromastix*, which is found only in the recent fauna of southern hemisphere (in Evenhuis, 1994 it is showed, that *M. bornhardti* Meunier, 1917 is described from the Oligocenic coals in France, when really it was described from the amber). I would say, that the most unique Limoniidae species in Baltic amber is *Polymera magnifica* Meunier, 1906. Recent species belonging to that genus are found only in tropical and subtropical America.

All species, known from the Baltic amber are extinct today; there are extinct 13% of genera and additionally nearly 8% of subgenera of recent genera. It could be seen, that differences between Baltic amber and recent fauna aren't big, most often they are at the species, and only sometimes at the genus or subgenus level. In some cases, especially in the family Tipulidae, it is impossible to say to which subgenus belong "amber" species, because they share features, which are common for few recent subgenera and together they are somewhat different too. Probably, differentiation into subgenera in that family developed somewhat later and all recent subgenera are comparatively young.

Two genera described from Baltic amber, later were found living. One of them is very common in the amber genus *Trichoneura* Loew, the other – *Styringomyia*

Loew, which probably was described from Dominican and mistakenly ascribed to Baltic amber.

Besides the amber, the only crane flies from the Lower Oligocene of Europe that are known are the interesting series described by Cockerell (1921) and Cockerell and Haines (1921) from the Bembridge beds at Gurnet Bay, Isle of Wight. A critical study of the descriptions and figures fails to show that any of these species are conspecific with those from the amber (Alexander, 1931). It is possible, that the elapsed time between the deposition of the Bembridge beds and the formation of the amber may have been few millions of years, a space of time amply sufficient to allow of distinct speciation in the two localities. List of species from the Bembridge beds adds one more neotropical genus to the Oligocene of Europe.

Totally there are known 150 species of crane flies from Baltic amber. These data are from the Catalogue of the Fossil Flies of the World (Insecta: Diptera) (Evenhuis, 1994) with addition of later described species. But some inaccuracies are left in this "Catalogue", for example, same species are listed under separate genera, because of different opinion of different authors; few species, probably were described from Dominican and mistakenly ascribed to Baltic amber; also there are species, which need to be counted as *nomen nudum*, because they do not fit with the requirements of International Code of Zoological Nomenclature (1999) – these are species, which, probably were seen by nobody, and their names were automatically transferred from older publications, where they were mentioned as such without descriptions, illustrations or even designations of type specimens. There are not known even museums or science establishments where these samples are preserved. There are 25 species of crane flies described by the author from Baltic amber.

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KANSAS AMBER: HISTORIC REVIEW AND NEW DESCRIPTION

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Abstract

Kansas is one of several sites worldwide in which Cretaceous age amber has been found. The purpose of this article is to provide a historic review and description, as well as to present new information in the form of infrared absorption spectroscopy data for this occurrence of amber from Kansas. Jelinite has similarities to other fossil resins in the cedarite group and the spectra of modern resin synthesized from the Araucariaceae.

A Brief Introduction to Cretaceous Amber in North America

Fossil resin and copal occur on the North American continent among strata from Triassic to Recent. The oldest amber on the North American continent is found in the Upper Triassic Chinle Formation, New Mexico, USA (Grimaldi, Nascimbene, Luzzi, Case, 1998, p. 81). The next oldest deposits of amber are Cretaceous in age. The most abundant North American Cretaceous fossil resins are from the states of Alaska and New Jersey, USA and from the provinces of Alberta and Manitoba, Canada.

Harrington (1891) reported one of the earliest Canadian Cretaceous amber finds and called this fossil resin chemawinite after the name of the nearby Chemawin Trading Post located in Manitoba. This Hudson Bay Company outpost was given the Chemawin name by the indigenous peoples of the area (McAlpine and Martin, 1969, p. 819). Klebs (1897) described and named this same Canadian fossil resin cedarite after Cedar Lake, a lake fed by the Saskatchewan River. Amber resembling cedarite occurs at Medicine Hat, Alberta, associated with the coal deposits in the Cretaceous Foremost Formation, and near Bassano, Alberta, referred to as Grassy Lake. Grassy Lake amber has yielded many fossils, including the oldest known mosquito (Grimaldi, 1996, p. 25).

Alaskan amber was first mentioned by Dall (1870), while amber found on the Atlantic Coastal Plain, eastern United States, was first reported in 1821 (Grimaldi, 1996, p. 27). The eighteen fossil resin sites along the Atlantic Coastal Plain, primarily New Jersey and Staten Island, New York, have been detailed by Grimaldi, Beck, and Boon (1989). The United States has other less abundant, little known Cretaceous deposits, two such deposits are in Wyoming and Kansas. An Upper Cretaceous (Upper Maestrichtian) fossil resin found in Wyoming was recently described by Kosmowska-Ceranowicz, Giertych, and Miller (2001). This fossil resin, reddish-yellow in color and very brittle, was found embedded in clay of the Lance Formation, a compact, lime-free grey loam. A Lower Cretaceous (Late Albian) amber, also termed jelinite, was found in Kansas. This amber was associated with the shale and lignite of the Kiowa Formation and is the subject of this review and investigation.