Amber from the Baltic

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Abstract: Amber has been prized for its gem and mythical properties for centuries. Its primary source is the Baltic coast of Poland and Kaliningrad. The fauna and flora found in Baltic amber relate to the climatic changes in the late Eocene, when the amber was formed during a period of warmer temperatures. Amber was extracted by "fishing" on the coast, and is now won by modern opencast mining at Yantarny on the Samland Peninsular of Russia. Amber is used to make ornamental jewellery and other products, but it is difficult to distinguish genuine amber from various substitutes, particularly copal.

Neolithic sites along the Wistula River have testified that Baltic amber has been richly prized for thousands of years, and has been traded for its ornamental value, with exports to the ancient world. The Greeks were aware of its static electrical properties and their name for amber, *Elektron*, gives us our name for electricity. Amber was correctly identified by Pliny the elder as fossilized tree resin and Tacitus mentioned in the second century AD that it was extensively worked for jewellery in Aquileia (near Trieste). Amber objects have even been found in Bronze Age sites in Britain, such as the Hove Cup, excavated from the Clandon Barrow in 1857 and now in the Brighton Museum. Since amber burns with a distinct sweet smell, it was also used as an incense, together with copal, frankincense and myrrh, which are all related materials, and it soon gained mythical and supernatural properties. Tacitus mentioned the Amber Islands, close to a large river in which the amber was found. With the arrival of the dark ages in western Europe, amber's true origin was largely forgotten. Medieval, and later, chroniclers described legendary islands from which the amber came, and suggested that amber was either the fossilized tears of the innocents who were drowned in Noah's flood, or fossilized sunbeams. Since the Middle Ages much was written on its medical and healing properties, particularly for disorders of the throat, "flux of the belly", poisoning and, according to Camellus Leonardus writing in 1502, "if laid upon a wife when she is asleep, will make her confess all her evil deeds". Small chips of amber are made into spider webs that are still hung in the rafters of cottages in some parts of Poland because of the alleged healing powers.

Wave-rolled amber with bark fragments (photo: Museum of the Earth, Polish Academy of Science [MEPAS]).

In the 18th century, scientists took an interest in amber, and started to investigate its real origins. Though not technically a mineral in the classic sense, it is often classified as a gemstone in the jewellery industry. The name (in English and Latin) is derived from ambergris, the waxy deposit secreted by sperm whales, which was then washed up on beaches and was purified to produce perfumes. Amber was considered to be a fossilised version, and it was also refined to produce a sweet amber oil that is still used in some products today.

Away from the major Baltic locations, amber is found worldwide, notably from Canada to Central America. Some of the world's largest deposits are mined in the Dominican Republic, in China, and in many countries of Europe. The oldest amber yet found is Upper Carboniferous and the oldest insects are preserved in Lower Cretaceous material. One insect-bearing deposit occurs within the Wealden sequence on the Isle of White. The youngest amber, dating from about 20 Ma, is found in Switzerland.

Amber necklace of about 100 BC from near Gdańsk (photo: Archaeological Museum Gdańsk).

Composition of amber

Amber is a generic term for a variety of fossilised resinous and bituminous substances extruded by conifers, with a general formulae simplified to $C_{10}H_{16}O$. Although of heterogeneous composition, most of these substances are bituminous and insoluble in water, but are soluble to a greater or lesser extent in alcohol, ether and chloroform. Younger material contains varying amounts of succinic acid, which crystallises over time, with an increasing loss of volatiles, through polymerization. While large, fairly pure, masses of late Tertiary amber can break with a conchoidal fracture, older amber from the Cretaceous tends be very brittle and will easily shatter.

Amber varies in colour from clear to dark red, with the well-known, rich, reddish yellows favoured for the production of jewellery. Bluish and dark brown varieties, sometimes called black amber, are also known. A variety sometimes prized as a gemstone, is succinite [containing 3-8% of succinic acid, $COOH(CH_2)_2COOH_{15}$], and the best of it comes from the Baltic area; its colour is white or a pale transluscent yellow, due to microscopic inclusions of trapped air. Other varieties based on their chemistry include gedanite (a resin containing much less succinic acid) and then various varieties of retinite, which contain up to 6 % oxygen but no succinic acid. Gedanite tends to be lighter and more brittle than succinite, so is less favoured by jewellery workers since it is difficult to work. Beckerite is much denser and harder than gedanite, despite being found in associated deposits. It takes a poor polish but does not break as easily.

The density varies according to the amount of trapped air bubbles and impurities; amber will sink slowly in still water, but can become suspended in agitated water, particularly saline water. Highly weathered (oxidized) amber is lighter and can float. It was formally thought that identification of the amounts of succinic acid could be used to allow ambers to be identified and dated; Baltic ambers usually having high proportions compared to other sources. This technique, only partly successful, has now been replaced by more sophisticated infrared and mass spectroscopy techniques.

Polymerization in amber results in macromolecules that give a high impermeability to water-based fluids, though micro porosity can occur and allow the escape of volatiles. Objects found in amber are preserved by being totally sealed rather than fossilised (i.e., there is no replacement by mineralization), which results in a very high level of preservation of the contents.

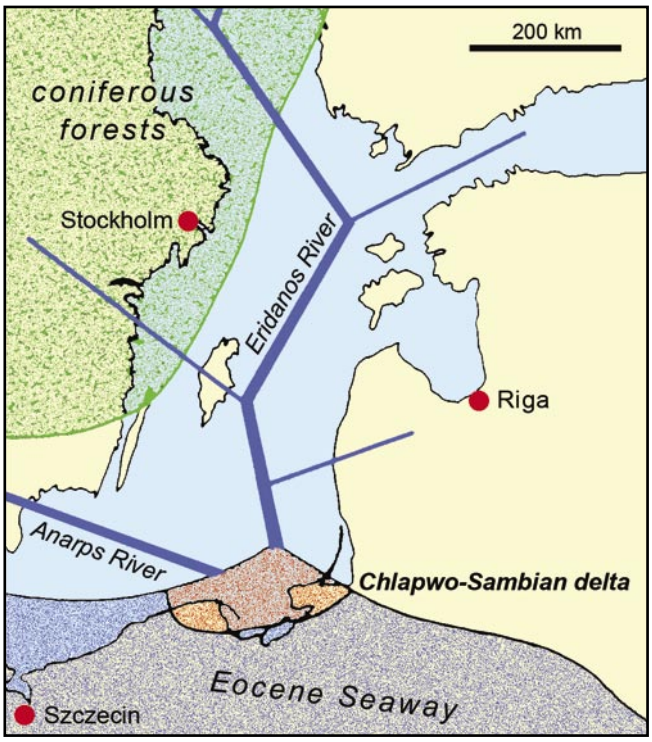
hardness (Mohs' scale)	2 – 2.5
density	1.05 – 1.96 Mg/m^3
streak	white
refraction index	1.54
melting point	250 – 300 ºC

Physical properties of amber

Succinite, white amber (photo: MEPAS).

Baltic amber: occurrence and origin

The southern Baltic region contains one of the world's largest resources of amber, and extends around the coastal areas of the eastern part of Poland, through the Kaliningrad Oblast (a detached enclave of Russia between Poland and Lithuania), and into the southwestern corner of Lithuania itself. Within the Kaliningrad enclave, the primary amber locations are on the Samland Peninsular. In Eocene times, this whole region was occupied by the Chłapwo-Sambian delta of the Eridanos and Anarps rivers, which together drained much of Scandinavia. The main streams appear to have followed fault lines, now occupied by the Kattergat and gulfs of the Baltic Sea, and flowed into a combined



The Eocene amber-bearing river system that carried the resin from its Scandinavian forest source to its Baltic delta (after Jaworowski and Holst).

A chunk of amber weighing 1.5 kg in the museum at the old factory in Yantarny.

delta in the area of today's southern Baltic. This delta formed on the margin of an Upper Eocene Seaway that extended from an enlarged North Sea, southeast across Europe, following the Tonquist line, to the Middle East. Two more deltas into this seaway, now lie buried to the southeast of the Baltic - the Parczew delta in east central Poland and the Klesev delta in the Ukraine. They also produce small amounts amber of similar age.

[Left] Fossil tree bark with tunnels of bark-boring beetles filled with amber resin (photo: MEPAS).

[Right] Drps of resin seeping from a scar on a modern spruce tree (photo: Emmanuel and Anna Boutet).

The resin-producing conifers grew within these rivers' catchment across most of Scandinavia and parts of western Russia. As the trees died, they were washed into the rivers and eventually to the delta where they were rapidly buried. Some of the wood rotted away, though much is preserved as lignite, but the resin survived because it changed to amber under the anaerobic conditions of diagenesis.

There is some controversy regarding which trees were responsible for the resin that formed the amber, principally since few trees today contain succinic acid in their resins. In the 19th century it was assumed that only one species, *Pinites succinifer,* was responsible; more recently it has been suggested that several species, possibly related to an ancestor of *Psudolarix kaempferi,* the Golden larch, now found only in Eastern China, are likely contenders. It is thought that gedanite may be from a totally different tree due to its low content of succinic acid.

Resin, not to be confused with sap (a mixture of water and sugars on which the tree lives), normally only exudes from the tree when it is under attack. Sea levels were high in the Eocene in response to the high temperatures of the Thermal Optimum around the Palaeocene-Eocene boundary. Although Baltic amber ranges in age from 35 to 45 Ma., about 10 Ma later than the Thermal Optimum, there were numerous strong oscillations of sea level at this time associated with blips in the general post-Optimum cooling trend. It is thought that the trees became stressed as the water table rose or fell during one or several such oscillations, leaving the trees more venerable to fungal and insect attack. This theory is supported by the situation in the Coast Range mountains of British Columbia today. There, many trees in the extensive highland pine forests are being rapidly killed by a fungus introduced by the pine weevil. In this case, dryness and warm winters have stressed the trees, and warmer winters are not killing the larval stages of the weevil. The infected trees extrude resin as a defence mechanism against the weevil. Evidence for similar stress in the Eocene amber forest lies in the large quantity of amber resin impregnated with worm holes and fungal debris. Many of the amber drips exceed 20 cm in length.

Polished pebble of amber containing an ant and various plant fragments (photo: Tony Waltham).

Mayfly, Ephemenoptera*, in Baltic amber (photo: MEPAS).*

Since the 17th century, scientific interest, made possible with improvements in microscopes, has focussed on the contents of the amber, particularly the great variety of insects and other small animals it contains. The most common animals found are insects, arachnids and myrapods, but small amphibians and a lizard have also been recorded. It is little wonder that the state of preservation led to the science fiction accounts of extracting DNA to recreate the dinosaurs in "Jurassic Park". Apart from indicating the inhabitants of the amber forests, their occurrence has suggested climatic changes since the deposits formed. Evidence for the local late-Eocene climate being generally warmer than today is provided by the many insects and beetles that are temperature sensitive; notably, the termite *Isoptera* occurs in the amber, but is now only found in tropical regions.

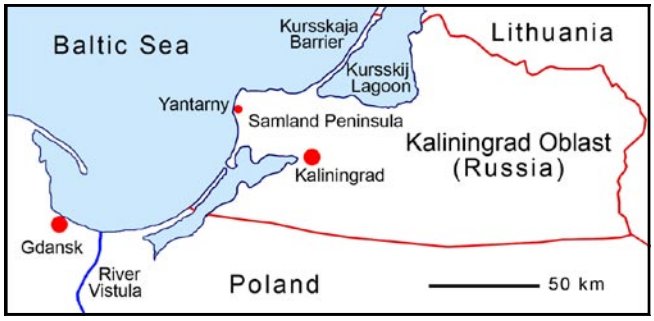
Spider, Aranea *sp., near its victim fly,* Diptera nematocera*, both encased in amber (photo: MEPAS).*

Fishing for amber after a storm, on the sand beaches of the Samland Peninsula during the 1930s.

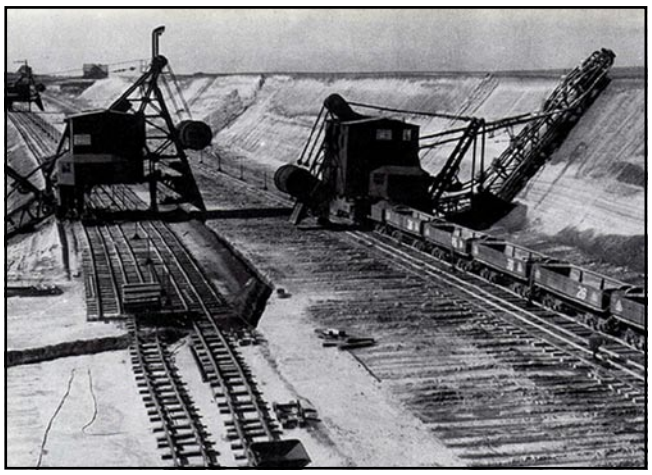
Amber mining on the Baltic

Until the 19th century, most amber was picked up from the sea shore of the Baltic. Due to its low density, it was easily dispersed by storms after being ripped from submarine outcrops and then transported landwards and westwards. Pieces of amber weighing around a kilogramme have even been found on the beaches and in offshore dredging along the Norfolk and Suffolk. Pleistocene glaciers also re-distributed amber across northern Europe; some notable finds in glacial deposits include a piece weighing 3 kg in sandy till near Tochula, central Poland. It is likely that such finds would have supplemented the amber industry in Neolithic times.

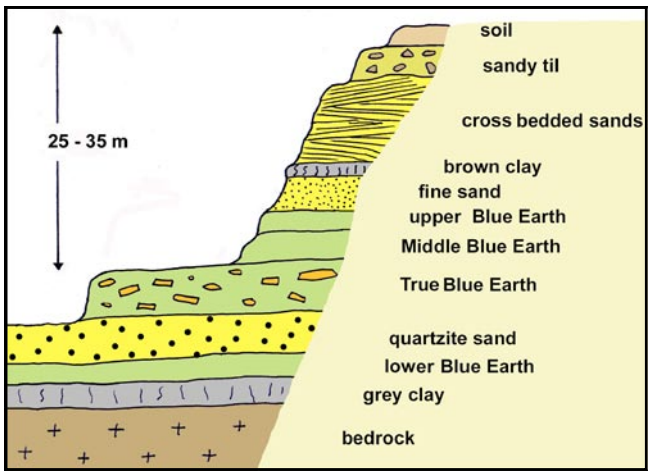
It was the Prussians who really put amber production onto an industrial scale, when they controlled the whole of the southern Baltic coast. Amber extraction from a buried Holocene beach, 12 m deep, still continues today in the Gdańsk area of Poland. However, the biggest area for amber production is the Samland Peninsula, once part of Prussia and then within Germany until 1945. In the 16th century the coastal area of the peninsula was cordoned off to try to monopolise the industry. Fishermen were employed with large nets to catch the amber in the surf when the winds were right. Today, these beaches on the peninsular and along the Baltic side of the Kursskaja sand barrier are a popular tourist destination for the Russians. One of their great pastimes is to look for amber, with the best time being after a storm, but pickings are small today.



Yantarny and the Samland Peninsula.



Overburden stripping at the Palmnicken mine in the 1930s.



Sketch section of the amber-bearing sediments at Yantarny.

In the mid-19th century, Messrs Stantien and Becker started to dredge for amber in the Kursskij Lagoon, behind the Kursskaja sand barrier on the north side of the Samland Peninsula. In 1875, they opened a mine just south of the Prussian town of Palmnicken (later renamed Yantarny, from the Russian word for amber); originally a small fishing village, its population rapidly expanded with the workopportunities in the amber industry. They eventually built their own Protestant miners' church in 1891, and today it is one of the few churches that is restored and used as an Orthodox church in the Kaliningrad Oblast. The original mine entrance was close to the beach, and during a storm surge in 1892, sea water flooded into the mine, drowning six men who were unable to escape.

A large opencast mine was then worked to reach down to the Blue Earth (a translation of the German *Blauerde*) that contains the amber. Even by 1930, the process of excavation had become very mechanised, with large draglines and bucket chain excavators removing the overburden. This pit was originally very profitable, as it yielded up to 3 kg of amber per cubic metre of the ore bed. It was abandoned when the overburden ratio rose to uneconomic levels, and the pit remains today as a lake 2 km long just to the north of town. The mine site and the nearby sea shore gained a notoriety as a war crime location at the end of the war, when 15,000 inmates from the Stutoff concentration camp, near Gdańsk, were marched there to be walled up in the disused mine workings. When the manager refused to comply with the wishes of the Gestapo, the prisoners were all marched into the sea and shot.

Today the Plazhovaya mine is a large opencast site, just to the east of Yantamy, which now boasts a population of 6000. Visitors are escorted (security is everywhere in this part of Russia) to a viewpoint overlooking the kilometre long active face of the quarry. Working eastwards, the miners are encountering increasingly deeper overburden, though the deposits themselves dip slightly to the west. The Blue Earth, the source of the amber, is a sandy silt that is greenish when fresh, due to high levels of glauconite. All three Blue Earths contain amber, and the Middle Blue Earth contains a large quantity of lignite from the forests. The main and richest layer, the True Blue Earth, varies in thickness from 17.5 m down to nothing, and yields up to 2 kg of amber per cubic metre in the current workings. Iinformation on the lifetime of the pit and any other geological data are all kept very secret. Within the mine, the Blue Earth is exposed by draglines that remove the barren overburden. The amber is then washed from the clay by high-pressure water jets from powerful monitor pumps, and where conditions allow the pumps are installed to wash the soil directly from the outcrop. Although about 600 tonnes of amber are produced annually at Yantarny, only about 10% of this is of gem quality, and less than 1% has preserved animal remains.

Current working in the Plazhovaya amber quarry at Yantarny, with three draglines along the main face that is partly hidden by the spoil heaps of overburden.

A piece of amber within the Blue Earth matrix.

Amber as a precious stone

Baltic amber's translucence, and the remarkable state of preservation of its contents, has meant that it has been one of the most highly prized gemstones used in jewellery for centuries. This is particularly the case for the red translucent varieties. Various small factories were established by the Prussians in the 19th century to sort and produce amber jewellery and souvenirs, though some was still produced by individual craftsmen. The main Prussian production areas for producing amber goods were Königsberg (Kaliningrad) and Danzig (Gdańsk), which were both important Baltic trading cities. The industry collapsed during both World Wars, when export through the blockaded Baltic became a problem. After 1945, the Russians revived the industry and, for security reasons, concentrated jewellery production into one large factory at Yantarny. This recently closed, but today it houses a museum displaying a whole variety of ornaments from pictures of Lenin to model churches, boxes and of course, jewellery, all made from amber. Security at the factory is extremely tight. Visitors are searched going in and coming out, and photography of the derelict buildings, outside the museum room, is strictly forbidden.

Necklace of pebbles of amber that each contain insects.

Sorting amber and making jewellery in the Yantamy factory.

A modern private factory has recently opened to the north of the town, where the processes of sorting amber and making jewellery can be observed and photographed, albeit through glass screens. Total Baltic amber output is estimated to be 800 tonnes annually. Russian output remains static, but greater Polish output from the Gdańsk mine is slightly increasing the total.

From the Renaissance onwards, amber has also been used as a decorative addition to pieces of furniture. Of historical note is the famous Amber Room, commissioned by King Fredrick of Prussia in 1701, for his palace in Berlin, which he later presented to Czar Peter I of Russia in 1716 to confer a friendship treaty between the two countries. The Amber Room was the largest work of art ever made out of amber. It consisted of 100,000 pieces of carved amber, accented with diamonds, emeralds, jade, onyx and rubies. Amber panels covered an entire room of 55 square metres, and they weighed more than six tonnes. They were backed entirely in gold leaf, and it took a team of craftsmen ten years to create. The room was eventually installed in Catherine Palace, outside St. Petersburg, and was enlarged by Catherine the Great, when many semi-precious stones were added. Captured by the Germans in World War 2, it was taken to Königsburg

The Amber Room in the Catherine Palace at St. Petersburg, as it was before World War Two.

Amber casket that was made in the 18th century.

(Kaliningrad) and displayed in the Castle in November 1941, but this was heavily damaged by British bombing in 1944. The Russians maintain that when they arrived in March 1945 the Amber Room had disappeared. Despite much accusation and argument, no fragment of the room has ever been found, and it remains one of the world's greatest lost treasures. It is possible that it was dismantled, packed and placed on the ill fated *Wilhelm Gustloff*, a ship carrying refugees that was torpedoed after leaving Königsburg in January 1945. However the hunt is still on and treasure hunters keep claiming to have found bits of it hidden at various locations in the pre-war German domain.

Between 1979 and 2003 an exact replica of the Amber Room was built, also within the Catherine Palace, with amber supplied by the mine at Yantarny.

Modified and fake amber

Following its mythological association with ambergris, much of the lower grade of amber is retorted to produce small quantities of amber oil for use in perfumes. About 2% of succinic acid can be also recovered, which is used in medicines and dyes. The residue, a dark pitch, can then used to produce a hard varnish, which has good waterproof properties, similar to copal varnish, but harder. This was traditionally used to varnish violins in the 17th century. Like amber, copal is also a semi-fossilised resin, but it is less diageneticly altered than amber so contains more volatiles, in particular the terpenes, which make it softer.

Amber casket on display in the amber museum within the old factory at Yantarny.

With its low melting point, it is easy to form amber liquid, and then to cast jewellery with it. Some of this processed or fake amber is quite obvious; modern house flies entombed in amber drops are commonly sold on stalls in Tallinn, Estonia, and many small animals such as frogs are incorporated into South American amber where faking is rife.

Much more cunning is the manufacture of items shaped from pressed poor quality amber after heat treatment to improve, darken and redden its colour. Generally the rich red varieties are preferred for jewellery. Much of this faking or "improvement" was formally done legally with the cooperation of the Russian authorities, but since 2002 the practice has been outlawed in Russia and Poland following a Russian-Polish-German conference of amber investigators in June 1996. Supplies of inferior amber are now regulated to prevent them being substituted for gem quality material, and security at the mine and factories is very tight in order to control theft. However, this 'ambroid' is still sold on street stalls all round the Baltic coast, and there are also many artificial plastic substitutes. The problems with antique amber are complicated since the Victorians experimented with bakelite, a variety of plastic that was used to imitate amber in the 19th century. Such items have now developed a patina of age that makes them difficult to distinguish from genuine amber with its own patina.

Many items reporting to be amber are in fact copal. The two can be distinguished by inserting a hot needle into the specimen. Copal melts easily and gives off a sweet smell, while true amber melts more slowly and produces a black smoke. Alternatively, acetone does not affect amber, but a few drops of it will start to dissolve the surface of copal, so that it becomes sticky. Amber will also not cut easily (it tends to flake and shatter) while many substitutes, particularly plastics, will produce shavings. It has been suggested that over half the 'genuine' amber in museums, as well as in high class vendors, is faked to some extent, so the old epithet of "buyer beware" remains very appropriate.

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