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# Geological Nature and Parent Primary Sources of the European Placers of Amber-Succinite

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Geological Nature and Parent Primary Sources of the European Placers of Amber-Succinite. — Matsui, V. M. — The issues of the origin of amber have attracted human attention since ancient times. The earliest plausible information on the amber origin belongs to Pliny the Elder (23–79 AD) who proved its plant nature. In the beginning of the 21<sup>st</sup> century all important stages of this long process from the resin outflow of gymnosperms, and its accumulation in the soil of the amber forest to further formation of amber-succinite deposits in sediments of the marine basin were described by the theory which however has some points wanting clarification. Eocene–Oligocene amber forest soil in the European platform has not been discovered yet. Based on the data of analysis of the Cenozoic coal basins in Europe, the geological position and the material composition of fossil resins, and paleogeography of the seas surrounded lignite basins of Germany, Poland, Byelorussia and Ukraine in the Eocene to Early Oligocene, H. Lebed' and V. Matsui came to conclusion that the primary source of amber–succinite in European deposits could be eroded layers of bitum-containing brown coal of buchak suite, and its stratigraphic analogues. In the light of the proposed conception, the bituminous brown coal formation is regarded as an indigenous origin of fossil resins and amber-succinite.

**Keywords:** amber-succinite, brown coal, Eocene-Oligocene.

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#### Introduction

Amber-succinite (Alatyr stone of pagan Slav myths) occupies one of the first places in the constellation of gem stones due to its beauty and variety of color, cleanliness and light permeability. It has unique physical, chemical and hygienically positive properties and occurs exclusively on the territory from Southern Sweden to the Black and Azov Seas coasts. This territory includes Denmark, Southern Sweden, and Northeastern Germany, Kaliningrad Oblast of Russian Federation, Lithuania, Southern Latvia, Southeastern Belarus and Northern part of Ukraine. In scientific and popular literature it is known as "Baltic-Dnieper Amber-bearing Province". Only there, in the marine Paleogene sedimentary sequences and recent beach sands the accumulation of amber-succinite (AS) reach significant commercial concentrations. The province is the main supplier of sun stone to world markets and study center of geology of fossil resins (FR) and AS in part. The history of development of unique treasures of the region begins since the Late Paleolithic end (14–18 Ka BC) that is indicated by numerous archeological finds in the kind of primitive products and pieces of unprocessed AS in dwelling of ancient mammoth hunters in the middle Dnieper current and Ukrainian Polissia. Since the Mesolithic (10–7 Ka BC), the "amber" coasts of the Baltic Sea are developed. The opinions about origin of various kinds of fossil resins repeatedly changed during the whole history of human society.

In widely known "Natural history" by Plinius Senior (23–79 AC) this author unequivocally and definitely wrights about vegetative origin of amber. On his view, amber originated from liquid pitch of coniferous (fur-tree) and hardened under influence of cold time or sea water, when it got in waves in the surf time. Later the sea throws out amber onto the coast.

During two millennia this idea before its final forming in the today theory of origin of fossil resins (FR) and AS passed a complex way of misunderstanding and even denying.

Since the depth of centuries uncountable inconsistent mentions and fascinating myths and legends came to us that described these gems as "Sun fragments" (monument with wedge-like of X Cnt. BC that is stored in British Museum, London); tears of Heliades, sisters of Phaeton, son of Sun god (from Aeschylus, 525–456 BC); petrified urine of lynx (Greek philosopher Demokrit, 460–370

BC) hardened clot of sun rays; sea surf foam that petrified under action of elements; products of life activity of large forest ants or bees, even hardened bird tears. With development of civilization, the origin of sun stone was related to liquid bitumen that discharged on the sea bottom from faults of the Earth crust and subsequently on air or considered it as a variety of rock coal jet (gagate). Amber was considered also as a special secretion of whales — ambergris (II Cnt. AC). This mixture of two notions in some wonder way persisted in science till 17 Cnt. At all variety of opinions that existed till 18 Cnt, thanking the scientifically proved facts (M.V. Lomonosov, J.F. John, O. Helm, H.Conwentz, P.A. Tutkovsky, N.A. Orlov, V.A. Uspensky, V.I. Katinos, V.S. Trofimov and others), the idea of vegetative origin of amber-succinite and fossils resins obtained the common adoption and further development. till the present time, all constituent links of long stages of fossilization have been described in detail, from secretion of pitch of productive species of coniferous trees and its accumulation in the soils of amber forests and peats to coming into marine basin and formation of AS placers in clayey-sand sediments of the sea coast and on the remote areas of the shelf. Finally, the finishing stage of diagenetic and epigenetic transformations of fossil resins in land and subsurface conditions since the end of the Oligocene till today [2–15] also has been elucidated. As a result, the idea-hypothesis by Plinius Senior transformed into the modern harmonious theory of amber origin though with some weak places. The most vulnerable link of this theory is the question about the genetic type and spatial position of parent primary sources of AS placer of first intermediate collectors that essentially its possibilities in the forecast studies. Non-solving of this question first of all related to that it not to give a due attention to the role of brown coal bitumen in amber forming process, which in essence is the only conservation agent of pitch secretions to their transformations in AS in the marine glauconite-containing environment

## Results of investigations and their analysis

In 2007–2009, N.I. Lebed and the author of this work substantiated the possibility of direct participation of brown coal bitumen (natural mixture of waxes and pitches in the amber formation process [2–5]. In the light of o the supposed hypothesis the Middle Eocene bitumen — brown coal formation containing FR is considered as placer-forming or as parent primary source of AS placers. The placers and FR are considered as natural organic matters of coal line. FR formed in young superimposed depressions of mountain-fold regions at the erosion of "non-mature" paleopeatbogs with low level of initial peat decomposition, and AS formed in quiet platform conditions under which bitumen-containing coals are characterized by complete gelation (decomposition) of peat. The suggested concept originated the necessity to revise a number of adopted notions and statements related to the development of the amber formation theory and formation of AS placers in the coastal-marine, marine and continental environments.

During the whole human history since the end of the Late Paleolithic dozens of thousand tons of high-quality AS were recovered from the placers on the territory of the Baltic-Dnieper Province, and its forecast reserves in the bowels are estimated in million tons. Such amount of same type resin of one mineral kind could accumulate in marine placers only as a result of erosion of parent primary sources of same geological type on huge areas of platform Europe which were the accumulations of brown coals and lignites. The manifestations of fossil resins and AS placers are paragenetically related to these accumulations.

A wide example is the concentration of placers in consideration along the boundary of the Dnieper Brow Coal Basin, common occurrence of AS in lenses containing brown coal and presence of surviving erosion brown coal sections of resinites and other kinds of FR.

The resinite inclusions in brown coals of the Dnieper Basins and their brief characteristics are described in the works of investigator of the basin's geological structure in 1930–1950s V.P. Chirvinsky, V.T. Siabriay [15], I.E. Slenzak and others. At this, the most promising amber-bearing placer are densely concentrated along the northwestern margin of the basin (NW margin of the Ukrainian

Shield), namely there where the bitumen seams of brown coal are almost completely eroded in the Late Eocene — Early Oligocene. The escaped of erosion complete sections of brown coal sequences of Buchak suite are almost everywhere covered by marine strata of Kiev, Obukhiv and Mezhigir suites.

The lower half of the Middle Eocene (50–44 Ma) was the time of global warming ("coal-bearing episode"), enlargement of the tropical and subtropical zones of the globe and their expansion in higher latitudes. It was the time of unusual natural contrasts when on the same territory and simultaneously zonally and ecologically most different types of vegetation were combined inherited to subtropical, tropical and temperate latitudes. Under these conditions, the plentiful pitch secretion of coniferous trees took place in Northern Eurasia including Araucariaceae, which disappeared on the territory under consideration in the end of the Eocene.

Dnieper Basin was not the only basin where the plentiful accumulation of fossil plant resins and accumulation of primary accumulation of protoamber passed. The analogous geological processes went in the most part of Scandinavia, Germany, Polish-Lithuanian Depression (in northeastern Poland, Kaliningrad Oblast of Russia, and Lithuania) and Belarus. Inclusions of krantzite and other kinds of FR are found also in brown coals of Germany. V.T. Siabriay made the conclusion about almost complete identity of floral remains from the brown coals of Germany and flora from coals of the Dnieper basin [15: p. 52–53].

The marine stage of transformation of plant resins into AS is related to a marine paleo-plain that since the second half the Middle Eocene connected the tropical ocean Tethys on the southeast and Northern Atlantic on the northwest.

It was promoted by a new uplift of the World Ocean's level and subsidence of Mazury-Belarus Uplift. As a result, in the end of the Middle Eocene (in post-Buchak time the Northwestern European marine basin through the sea on the Belarus' territory was connected with the Eastern European basin that through the Donbas, Scythean Plateau and Mangyshlak joined to the adjacent regions of the Caspian and Black Sea Depression. Then it ran to the Caucasus, Palestine and Iran [16]. In that time, over 70% of the Ukrainian Shield (Dnieper Basin) sank in water of the Kiev Sea and became an island land (the presence of continental analog of Kiev suite is not recognized in general). In the conditions of formed paleogeographic environment no reasons exist to suppose the presence there any significant areas of "amber forests" and concentration of coniferous pitch secretions. On the bottom of the Kiev Sea, glauconite-sand phosphorite-bearing and marl layers accumulated that discordantly covered both the formations of crystalline basement and oldest sequences of sedimentary cover (including coal-bearing Buchak). The epoch ended with the insignificant sea regression and partial erosion of predominantly upper over-coal horizons. As a result, poor AS placers formed that had only mineralogical interest.

The most intense erosion of bitumen-containing brown coal strata and carrying of protoamber into the coastal zone occurred in the Late Eocene (Obukhiv transgression) and Early Oligocene (Mezhigir transgression). In that time, the sea washing the territory of Northern Ukraine was a typical epicontinental basin which differed from the Middle Eocene (Kiev) one in somewhat shallower depths, especially in the water areas adjacent at the north and northwest to the land, Dnieper Basin.

The AS placers of primary intermediate collectors with commercial contents are related to the transitional Eocene and Oligocene layers of the Baltic-Dnieper Amber-bearing Province. The unique accumulations of sun stone (up to 80% of world reserves) are known from old antiquity on the Sambika Peninsula (Kaliningrad Oblast); they are related to the Upper Eocene marine deposit (Prussian suite). In Ukraine large AS concentrations in the Obukhiv suite sediments of same age are till unknown. Here they in a large degree eroded in the Oligocene, Neogene and Pleistocene times and could preserve till our days only in individual locations of buried Paleogene relief. Near-surface coastal-marine and deltaic amber-bearing deposits (placers) of Mezhygir suite (Early Oligocene) linked with the epoch of reduction of marine basins and gradual separation of southern and northern seas.

So, the richest on content AS placers of first intermediate collectors (parent placers, after P.A. Tut-kovsky) formed in the Late Eocene and Early Oligocene as a result of direct erosion of parent primary source. All following (local, poor on content) AS placers are results of products on multiple continental erosion and redepositions of the early formed placers in the end of Oligocene, Neogene and Pleistocene ages.

Specifics of the protoamber catagenesis processes outwashed from parent primary sources, features of geochemical environment in "blue earth" of marine basin are described in details by S.S. Savkevitch [11]. On his data "The influence of external environment over buried resin manifested in series of its chemical transformations [11, p. 165–166]. In alkaline environment oxygen-containing and potassium-enriched mud waters interacted with resin and promoted the current of a number of intermolecular transformations which led to the formation of various oxycombinations and splitting of amber acid in free state and its ethers in combination with some changes of physical properties.

At the erosion of brown coal and lignite strata in the end of Eocene — Early Oligocene and transportation of protoamber in alkaline environment of sea bottom only those protoamber bodies could pass into AS which were outwashed from "mature" paleopeatbogs. The preserved parts of them are represented in brown coal seams with inclusions of small clasts of retinite on the territory of the Dnieper Basin. It is in accordance with the facts of common occurrence of AS and other kinds of fossil resins as "rotten amber" (gedanite), "non-mature amber" (Baltic krantzite), glessite, beckerite, stantienite in the placers of Ukraine and Baltic region. These facts convincingly testify to the secondary nature of free amber acid in AS and appearance of new physical-chemical properties in the alkaline glauconite-containing environment of the sea bottom.

With post-Paleogene erosions of bitumen-containing brown coals both of marine and continental genesis the AS placers are not found and they are represented exclusively by fossil resins. The good example is Starodubovka FR placer (content of retinite up to 272 g/m³) connected with recent coastal-marine sediments at the Eastern coast of Southern Sakhalin [17]. They are sand-gravel-pebble formations filled with bunches of algae, clasts of mollusk and crab shells, crusts of echinoids, pieces of wood as well as coal clasts (often including retinite grains of various sizes and forms. The parent primary source of these placers are coal-bearing are the coal-bearing formations of the coastal zone and central part of Southern Sakhalin.

Therefore, the Neogene-Quaternary including Holocene and Recent coastal-marine or continental (alluvial, lacustrine-alluvial, water-glacial, eolian etc.) AS placers originate and form exclusively due to the erosion of older AS placers and FR placers for the account of the Middle Eocene brown coal sequences and lignites containing that or other kinds of FR. For example, on the coast of the Baltic Sea coastal-marine placers (or placers of marine beaches) form in the historical time mainly due to the erosion of Middle Holocene AS placers (7.1–1.94 Ka) related to the sediments of the Littorina Sea and, in smaller degree due to the erosion of Paleogene productive horizons of AS. In its turn, the Littorina brackish-water layers that have AS in their content (up to 0.2 kg/m³) and occur at 4–15 m beneath the sea level were formed mainly through the erosion of the Paleogene AS placers.

## **Conclusions**

Bitumen-brown coal accumulation of lower part of the Eocene on the Baltic-Dnieper Amberbearing Province is a real geological target through erosion of which in the marine glauconite-containing environment the huge volumes of placer AS formed on the extensive territory from the British Islands to the Black and Azov Seas. This conclusion contradicts the existing ideas about the role of the hypothetic Paleogene "amber pines" as the geological primary source of AS. Amber-succinite of the Baltic Province formed in the quiet platform conditions during two large changing in time stages:

1. Land-swamp (later half of the Middle Eocene) with the accumulation and forming of primary accumulations of resin secretions of coniferous trees (protoamber) in paleopeatbogs (sedimentation and diagenetic stage in the conditions of humid type of lithogenesis and

**2. Marine** (end of the Middle Eocene — Early Oligocene) with deposition sedimentation and sorting of outwashed from paleopeatbogs protoamber in the marine sedimentary basin. There, in a sharply changed geochemical environment the structural transformations went which caused the characteristic properties of amber-succinite as the unique and valuable variety of amber. The most important of them are: viscosity; higher content of amber acid; rather perceptible solubility (up to 20–30 %); high level of decorative properties and others. Washed out from paleopeatbogs with complete gelation (decomposition) protoamber obtains the mentioned above properties exclusively as a result of the interaction with the alkaline environment in the marine basin. Besides, only in the marine water area (in difference from other kinds of fossil resins)

AS placers of first intermediate collectors formed which in places reach high commercial concentrations.

All another mineral kinds of fossil resins that we known did not pass the stage of marine transformations or are products of non-mature paleopeatbogs and lignites with low level of decomposition of initial peat are related mainly to young superimposed depressions of mountain-fold mobile regions.

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Геологічна природа та корінні першоджерела Європейських розсипів бурштину-сукциніту. — Мацуй В. М. — Питання про походження бурштину турбують людство з найдавніших часів. Рання правдоподібна інформація про походження бурштину належить Плінію Старшому (23–79 рр. н. е.), який довів його рослинне походження. На початку XXI століття, всі важливі етапи цього тривалого процесу — від витікання смоли голонасінних дерев, її накопичення в ґрунті бурштинового лісу до подальшого формування протобурштину в глауконітмістячому середовищі морського басейну — описані теорією, яка проте має деяку кількість пунктів, що потребують з'ясування. Еоценові та олігоценові бурштинмістячі лісові ґрунти в межах Європейської платформи досі не виявлені. На підставі даних аналізу буровугільних басейнів кайнозою в Європі, геологічного положення та речовинного складу викопних смол, а також палеогеографії морів, які оточували буровугільні басейни

Німеччини, Польщі, України і Білорусії в еоцені–ранньому олігоцені, Н. Лебідь і В. Мацуй прийшли до висновку, що основним джерелом бурштину-сукциніту в європейських родовищах можуть бути шари бітуммістячого бурого вугілля бучакської світи та її стратиграфічних аналогів. У світлі запропонованої концепції, бітуммістяче буре вугілля розглядається як корінне першоджерело європейських розсипів бурштину-сукциніту.

Ключові слова: бурштин-сукциніт, буре вугілля, еоцен, олігоцен.

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Геологическая природа и коренные первоисточники е00вропейских россыпей янтаря-сукцинита. — **Мацуй В. М.** — Вопрос о происхождении янтаря беспокоит человечество с древнейших времен. Ранняя правдоподобная информация о происхождении янтаря принадлежит Плинию Старшему (23-79 гг. н.э.), который доказал его растительное происхождение. В начале XXI века все важные этапы этого длительного процесса — от истечения смолы голосеменных деревьев и её накопления в почве янтарного леса и последующее формирование протоянтаря в глауконитвмещающей среде морского бассейна описаны теорией янтареобразования. Однако некоторые вопросы теории требуют уточнения. Эоценовые и олигоценовые янтаревмещающие лесные почвы в пределах Европейской платформы до сих пор не обнаружены. На основании данных анализа буроугольных бассейнов кайнозоя в Европе, геологического положения и вещественного состава ископаемых смол, а также палеогеографии морей, которые окружали буроугольные бассейны Германии, Польши, Украины и Беларуси в эоцене-раннем олигоцене, Н. Лебедь и В. Мацуй пришли к выводу, что основным источником европейских россыпей янтаря-сукцинита могут быть слои битумсодержащего бурого угля бучакской свиты и ее стратиграфических аналогов. В свете предложенной концепции, битумсодержащий бурый уголь рассматривается как коренной первоисточник европейских россыпей янтарясукцинита.

Ключевые слова: янтарь-сукцинит, бурый уголь, эоцен, олигоцен.

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