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Morphogenetic types of amber traps in the Pripyat amber basin

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Abstract. The amber industry in Ukraine requires the expansion of its mineral resource base. This requires a scientifically sound, modern methodological basis for the "amber forecasting and prospecting system", which will allow the amber industry to develop systematically, addressing environmental, socio-economic, scientific, educational, and educational issues in a comprehensive manner. It takes into account all known theories of amber formation and uses the main scientific and methodological approaches to prospecting for various minerals. The *Pripyat Amber Basin* is the most important of all amber basins in Ukraine, which will provide the main increase in amber production in Ukraine. The geological, paleogeographic, geomorphosystemic, and paleogeomorphological factors of the development of its territory and the formation of alluvial amber deposits here are well studied. This makes it possible to introduce the concept of "amber-bearing formation" and "amber-bearing object", to create a classification of types of amber placer deposits, confirmed and predicted. According to it, structurally-tectonic, geomorphological, paleogeomorphological, morpholithogenetic and combined types of traps of amber can be distinguished. The article discusses morphogenetic types of traps that belong to their combined type and are studied by geological and geomorphological methods.

1. Introduction

In recent years, Ukraine has been developing a branch of the economy that includes amber forecasting, prospecting, mining and processing. For its effective development, a scientifically grounded "amber forecasting and prospecting system" (AFPS) is needed, which is created on a modern methodological basis (system theory). The AFPS takes into account all the main theories of amber formation and uses the main scientific and methodological approaches in prospecting for various minerals. The AFPS addresses environmental, socio-economic, scientific, educational, and educational issues in a comprehensive manner [1-3, 5-6, 11-13]. The Ukrainian AFPS is aimed at expanding the mineral resource base of the country's amber industry through a deeper study of known deposits, including *Pripyat Amber Basin* (PAB), and the discovery of new, hitherto little explored types. The Ukrainian



AFPS uses the concept of an “amber-bearing formation” (AF), in which systemic connections of tectogenesis, morphogenesis, lithogenesis, and oreogenesis of amber occur. The main practical goal of the AFPS is to identify “amber-bearing objects” (AO) – (traps) of placer amber deposits. The studies of the factors of AF formation within the PAB allow us to predict structurally – tectonic, geomorphological, paleogeomorphological, morpholithogenetic and combined types of amber traps. They are studied using scientific and methodological approaches, such as stratigraphic, lithological-stratigraphic, lithological, structurally-tectonic, paleogeomorphological, geomorphological, and geoecological.

The aim of the study was to investigate the structure and genesis of some established and potential morphogenetic traps of the PAB territory, which are classified as their combined type.

2. Methods

Methodological algorithms from scientific theories and methods can be used in the research of the AF of the PAB:

- general theory of systems in the selection of AF elements;
- geological-formational in establishing spatial and temporal parameters of the AF of the PAB body;
- geomorphological formation in the selection of elements of the geomorphosystem of the time of formation of the AF of the PAB;
- paleogeographical in determining the role of various natural (geological, geographical, etc.) factors in the formation of the AF of the PAB;
- paleogeomorphological in the study of paleoreliefs of individual stages of the AF PAB formation;
- structurally-tectonic and morphostructural analysis to create a geostructural and morphostructural basis of the PAB territory;
- neotectonic analysis to identify neotectonic structures of the PAB territory;
- lithological and facies analysis to determine the lithological and facies conditions of the PAB the AF formation;
- morpholithogenetic for the combined study of the processes of amber morphogenesis, lithogenesis and oreogenesis;
- regional morphochronodynamic analysis in the study of statics and dynamics of the geomorphosystem of the PAB territory;
- analysis of aerospace sensing materials (MASS) and digital relief models (DRM) in the study of the types of amber traps exposed on the earth's surface;
- laboratory modeling to study the behavior of amber in various hydrodynamic conditions;
- cartographic modeling to create cartographic models of PAB.

3. Results and discussion

The main elements of the AFPS at the level of theory are the AF and practice – AO. The AF includes theories of amber origin and scientific-methodical approaches to its study.

According to the known theories of amber origin, it was formed in 3 stages.

At the first stage, the oleoresin flowing from the tree took the form of a drop, formed clusters and growths that separated from the trunks and fell into the soil. The release of oleoresin could last for a long time, temporarily stop, and resume again. This led to the formation of numerous layers that determined the texture of the future amber. The resin became hard and fossilization began. Evaporation of volatile components increased the viscosity of the oleoresin. This was influenced by temperature, lighting, and the presence of ozone. Oxidized resin acids were converted into rosin. The resins darkened, became denser and harder. In the "amber forest" these processes lasted for hundreds of years.

At the second stage, the hardened resin accumulated in forest soils and formed soil-biogenic deposits that are of little practical importance. At this stage, active resin fossilization – physical and chemical processes of resin transformation – took place. This depended on the environmental conditions in which the resin was exposed. In aerated soil, the resin was transformed by oxygen. The resin became harder,

turned yellow and formed a weathering crust. In wetlands, the resin remained brittle. The warm and humid climate favored the decomposition of dead plants. This stage lasted longer than the previous one. The third stage was the final one in the formation of amber, lasting the longest - thousands and millions of years. It began with the erosion of soils containing primary biogenic deposits of fossilized "amber forest" resin, which, along with derivatives of "amber forest" soils, was washed into river valleys and then into sea water. In the alkaline paleohydrochemical environment of the sea, with the participation of glauconite, the oxidized resin was converted into amber. The most important properties of amber-succinite were formed in the sea, and succinic acid and its esters appeared.

In the sea basin and at the mouths of the rivers that flowed into it, fossil tar was buried in sand and silt deposits. This was influenced by the bottom and coastal zone relief, the nature of the coastline, and paleohydrodynamic conditions (wave regime, sea currents, and sea level fluctuations). Thus, in the Late Eocene - Early Oligocene, marine, coastal and deltaic amber deposits were formed on the western slope of the Ukrainian shield.

The concentration of amber in sedimentary rocks was influenced by the paleohydrochemical conditions of the marine environment and the amount of fossil resin that entered the marine basin. The paleohydrodynamic factor was not active at this stage. Therefore, high concentrations of amber are found in both coarse- and fine-grained sediments and almost horizontal occurrence of amber in them.

Its low specific gravity and high buoyancy contributed to the movement of amber over long distances, with little or no grinding or rolling [4, 8-10, 14, 17].

In the following geological epochs, amber was constantly redeposited. Starting from the Middle Eocene, a materially-morphological formation (body) appeared in the geomorpholithosphere of this territory, in which primary and repeated amber placers are stored. In our opinion, a geologically-formation approach can be applied to it. According to which, AF is a special type of sedimentary geological formation in which its central formation-forming element (amber) came from above (from trees), and not from below (as in most geological formations). At the same time, the AF, like all geological formations, is formed by the processes of tectogenesis, morphogenesis, lithogenesis, and amber oreogenesis, which interact systematically. As a result, tectonic (neotectonic) structures, landforms, sediments, and amber deposits are formed. The Ukrainian AF is being studied. But, in general, its spatial and temporal parameters, structure, and trends of transformations of the geological "body" of the AF are clear. Within the PAB, the geological body of the AF is almost everywhere exposed on the surface where it intersects with modern (and ancient) "geomorphological formations" of the territory. In view of all this, the research of AF for the purpose of detecting AO is based on separate scientific-methodical approaches: stratigraphic, lithological-stratigraphic, lithological, structural-tectonic, paleogeomorphological, geomorphological, and in recent years – geocological. The stratigraphic approach refers to the stratigraphic horizons of the Paleogene system (Kharkiv, Mezhyhiria, Obukhiv strata) in which primary amber-succinite deposits are found on the territory of Ukraine. This also includes the stratigraphic horizon of the buchach svita of the Middle Eocene, whose amber-like resins are considered by researchers to be the source for the formation of AF in Western and Eastern Europe (and Ukraine). The purpose of the lithological-stratigraphic approach (method) is to differentiate (zoning) prospective horizons and identify lithological reservoirs of primary amber deposits based on the use of empirical data. The lithological approach (method) allows us to identify: similar lithological reservoirs in the Neogene and Quaternary stratigraphic horizons; "through" lithological "bodies" formed during the erosion and redeposition of amber from Paleogene productive strata, at the transition to the Neogene and Quaternary stratigraphic horizons. The structurally-tectonic approach (method) in amber research is more declared, since ancient tectonic schemes are used formally, which, in this case, is not enough. Here, a completely different structural and tectonic model of the tectonosphere for the time of the AF existence is needed. It should show tectonic (neotectonic) structures that are dynamically active in the Neogene-Quaternary (neotectonic) time - newly created and inherited from morphostructures formed here since the Mesozoic. The dynamics of these structures largely determined the processes of lithogenesis and morphogenesis from the time of the beginning of the accumulation of amber-like resins (Middle Eocene), which were the basis for the formation of amber-succinite and its deposits (Late Eocene-Oligocene), subsequent

erosion of deposits, redeposition of amber from them and the formation of repeated placer deposits in the Neogene and Quaternary stratigraphic horizons during the Neogene-Quaternary stage. The paleogeomorphological approach (method) is partially used in prospecting and exploration by the organizations of the National Geological Company of Ukraine in the complex of traditional paleogeographic reconstructions for the time of accumulation of amber-like resins (Middle Eocene), as well as for the identification of promising elements and forms of ancient relief of the time of amber-succinite formation (Oligocene). The geomorphological approach (method) in the practice of organized amber prospecting, which is currently carried out by public and private organizations and companies, is used sporadically and not effectively. It is mainly used in situational plans of deposits to link them to certain elements, forms, genetic types and categories of relief. The achievements of geomorphological science, which specifies the concept of "relief" as a "geomorphosystem", are not taken into account at all.

It should be added that environmental protection in amber mining areas should not be limited to compliance with the recommended environmental standards and requirements (reclamation of disturbed lands and soils, restoration of woody vegetation). A comprehensive geo-environmental analysis must be carried out, which begins with an environmental assessment of the geomorphosystem of the entire territory. The conclusions obtained in this process provide additional criteria for assessing the already identified AO.

The main practical goal of the AFPS is to identify AO – natural formations and their parts that contain and may contain significant amber accumulations. Understanding of the structure of the AF and its elements (tectogenesis, morphogenesis, lithogenesis, oreogenesis of amber) and the existence of systemic links between them allows predicting and detecting the main types of the AF (traps): structural-tectonic, geomorphological, paleogeomorphological, morpholithogenetic, combined. Morphogenetic amber traps are of the combined type and may be of considerable interest in view of the expansion of the mineral resource base of the amber industry of Ukraine. The PAB is located on the territory of the Ukrainian shield and its western slope, the Volyn-Podilsk Plate. Figure 1 shows the geological profiles of the eastern part of the PAB (Ukrainian shield).

The article presents the results of the study of, in our opinion, promising amber traps of morphogenetic type, which are developed on the territory of the PAB hump and "ridge-hump"; linear-ridge accumulative forms; lake basins; karst relief forms.

Hill and "strand-hill". Individual hills and morphological combinations of "ridge-hill" are typical for the moraine and moraine-zandra plains developed in the PAB. Studies show that the relative height of the hills is 3–30 m. The hills are isometric, rounded and oval in shape, ranging in size from tens of meters to 1.5 km. There are also elongated hills such as ramparts or ridges. The height of these forms is 5–20 m, width – 50–70 m. Some ridges extend for 1.5–3 km, and their width at the base of the slopes is 100–600 m. The hills and ridges mostly have symmetrical slopes, and their tops have flat surfaces.

The MASS show that hills and ridges often form ridge and hill landscapes, which are often arranged in strips oriented in different directions. These positive landforms often look anomalous for the flat surface of the PAB. Researchers explained them by the action of the Dnipro glacier and glacial streams (kams, ozy). In the 70-s and 80-s of the 20-th century, drilling results during detailed geological survey and prospecting and exploration work provided new data on the geological structure of these forms. It turned out that the cuts of sedimentary rocks under some hills differs from the neighboring areas and they are often located above depressions in the surface of the crystalline basement rocks, which are filled with pre-Dnipro glacier sediments (Lower Quaternary, Neogene, Paleogene, Cretaceous) (figure 2). In some cases, the moraine of the Dnipro glacier lies directly on crystalline rocks and is referred to as drumlins.

In general, it should be noted that positive landforms have anomalous thicknesses of sedimentary cover and individual lithologic and stratigraphic horizons. They are either straight or reversed relatively to the buried surface of the crystalline basement. Under the hills, there is a sharp change in the lithological composition of rocks. Geological data indicate that accumulation basins used to exist at the site of the positive forms.

The analysis of the position of individual hills and their groups and tectonic structures allows us to

conclude that they are influenced by a structural factor. Bands and areas of ridge-hills landscapes are confined to major tectonic zones, and within the latter – to areas of intersection of zones of different directions. Mainly, the zones of submeridional and sublatitudinal strike are manifested, and to a lesser extent – of northwestern and northeastern directions. Detailed geological and geophysical works, confirmed by drilling results, show that individual hills are framed in the basement by tectonic faults of different directions.

In general, the analysis of the morphology and geological structure of the positive relief forms of the modern surface allows us to draw the following conclusions. There are no typical end-morphic forms within the PAB area on the Ukrainian shield. According to the data set, they can be attributed to drumlins, kams, and rarely to ozys. The latter are absent within the moraine plain, and the moraine-zandra plain is mostly composed of submarine water-glacial and lake-water-glacial formations, which are often overlain by moraine.

Evidence suggests that the processes of formation and subsequent transformations were accompanied by active movements of neotectonic blocks of the crystalline foundation. Some of these forms are of denudation-tectonic origin and are caused by high amplitude neotectonic uplifts of these blocks. These blocks remain active throughout the Meso-Cenozoic.

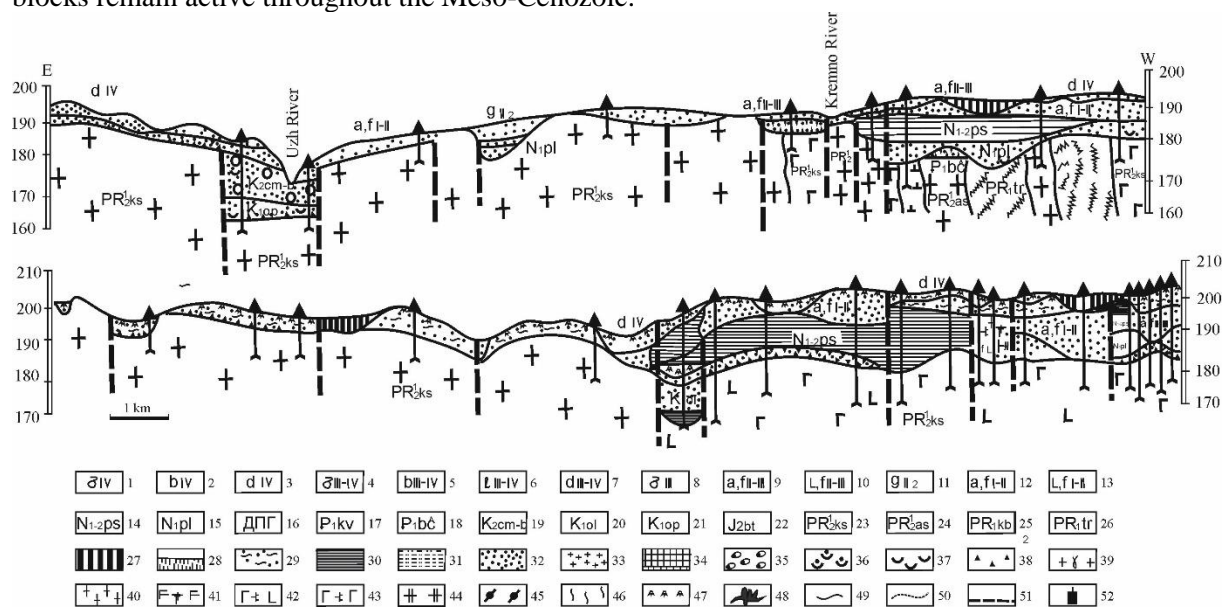


Figure 1. Geological cuts of the eastern part of the Prypiat amber basin (by O. Komliev).

Symbols to cuts: Modern sediments: 1 – alluvial; 2 – marsh; 3 – deluvial. Upper Quaternary-modern sediments: 4 – alluvial; 5 – marsh; 6-lalacustrine; 7 – deluvial; 8 – upper Quaternary alluvial. Middle-Upper Quaternary sediments: 9 – alluvial and water-glacial; 10 – lacustrine and water-glacial; 11 – middle-quaternary glacial; 12 – alluvial and water-glacial; 13 – lacustrine and water-glacial. Neogene system: 14 – mottled clays; 15 – Poltava svita. Paleogene system: 16 – Kharkiv suite; 17 – Kyiv suite; 18 – Buchak suite. Cretaceous system: 19 – Cenomanian-Turonian stage; 20 – Albanian stage; 21 – Aptian stage; 22 – Jurassic system, Bathian Stage. Proterozoic: 23 – intrusive formations of the Korosten complex; 24 – metasomatic and intrusive formations of the Osnytsia complex; 25 – ultrametamorphic formations of the Kirovograd-Zhytomyr complex; 26 – metamorphic formations of the Teteriv series. Lithological designations: 27 – peat; 28 – loam; 29 – moraine loam; 30 – clay; 31 – aleprite; 32 – sand; 33 – gravel and pebbles; 34 – sandstone; 35 – silts; 36 – kaolin secondary; 37 – kaolin primary; 38 – gruss; 39 – granites, coarse-medium grained; 40-granites, fine grained; 41 – anorthosite; 42 – gabbro-anorthosite; 43 – gabbro; 44 – siennite; 45 – diorite and plagiogranite; 46 – gneiss and pegmatite; 47 – amphibolite. Other designations: 48 – wells; 49 – boundaries of different age formations; 50 – lithological-facies boundaries; 51 – tectonic disturbances; 52 – high content of useful component in the rock.

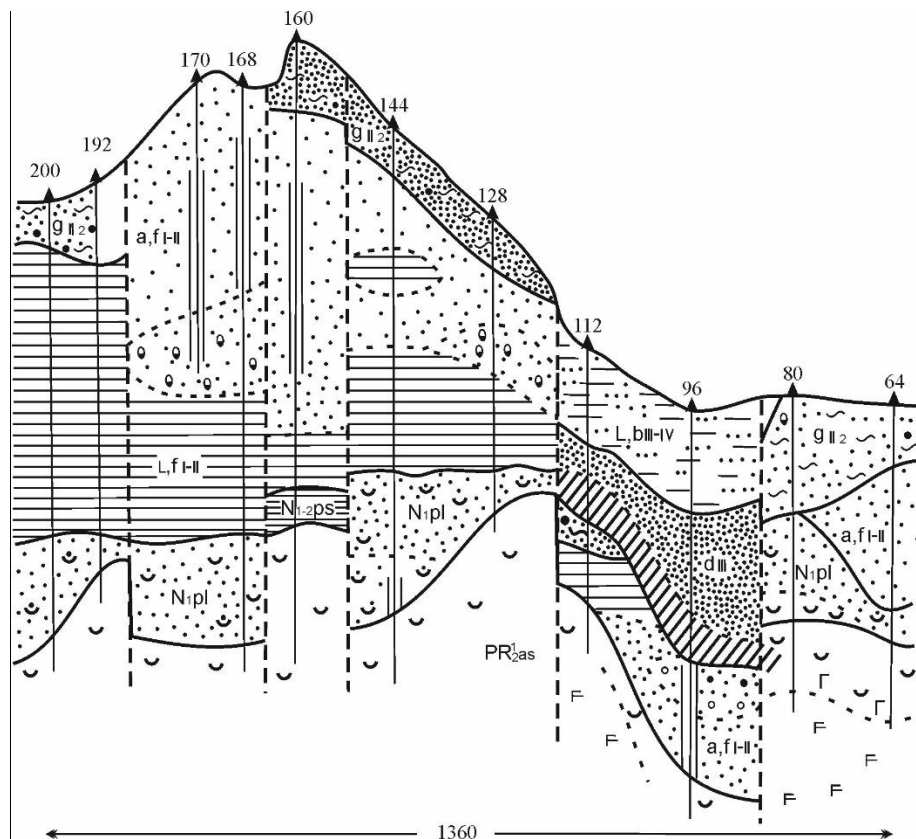


Figure 2. Geological structure of individual hills. Bezliv, Zhytomyr region (symbols in figure 1).

Linear-ridge accumulative forms. The most common forms of accumulative relief in the PAB are linearly elongated sand ridges. Researchers traditionally attribute these forms to aeolian formations or those associated with the accumulative activity of glaciers and water and glacial streams. However, detailed work carried out in the late 20th century revealed new patterns in their distribution, morphology, and structural confinement.

In the relief of the modern surface, these ridges are narrow, linearly elongated positive forms that extend from tens of meters to 20–30 km. They are 10–150 meters wide and 1–25 meters high.

The distance between these ridges is from 70 m to 1.5 km. Most of these ridges have a narrow ridge and a clear asymmetry of slopes. In the cross-sectional profile, the ridge can be complicated by small depressions and troughs that are oriented in the direction of the ridges.

The planned configuration of the ridges in the area is quite diverse. The most common strands are straight, elongated, acute-angled, annular, semi-annular, oval, and parabolic. Combinations of these shapes are even more complex. Strands of a certain type are often grouped in separate areas. Sometimes individual large strands are split or "telescoped" into each other. The diameter of ring ridges reaches 700 meters, while parabolic ridges are no more than 100 meters.

The ridges have different directions of strike, but the predominant direction is west-northwest. In parabolic ridges, the convex side of the parabolas is more often oriented to the east and north-east.

In the intersection of parallel rectilinear strands, steep slopes can be oriented in different directions, and in parabolic strands, the gentle slope is confined to the outer convex side. In ring strands, the outer slope is usually gentle.

Despite the variety of strands in plan and direction, there are no cases of their adjacency and overlap, except for strands of simple configurations.

The ridge relief is developed in areas composed of loose sediments of different age and genesis. Usually, the ridges are composed of well-sorted layered sandy strata. In many cases, they contain

crushed stone, gravel, pebbles, and small boulders.

The strands cross or parallel watershed lines. They are consistent with modern river valleys, terraces, and marshlands. They are absent from floodplains.

Various anomalies in the relief are associated with the ridges (deformations of longitudinal profiles, changes in surface morphology, the presence of dead valleys, and unusual development of bogs).

Many data show the association of the ridges with tectonic and neotectonic faults and block structures. Beneath the ridges, tectonic faults, crushing zones and linear weathering crust, clear ledges in the buried relief, and abrupt changes in stratigraphic and lithologic horizons are found. The ridges are sometimes located on the boundaries of buried grabens, which are filled with sediments of different ages.

Straight-line ridges are confined to certain azimuthal systems. There is a complete coincidence between the direction of the ridges and the zones of neotectonic faults. Parabolic strands are most common where the angle between faults is 60 – 1200 m. In most cases, parabolic closures of the west-west-northwest strike-slip faults occur when they cross large submeridional zones (figures 3).

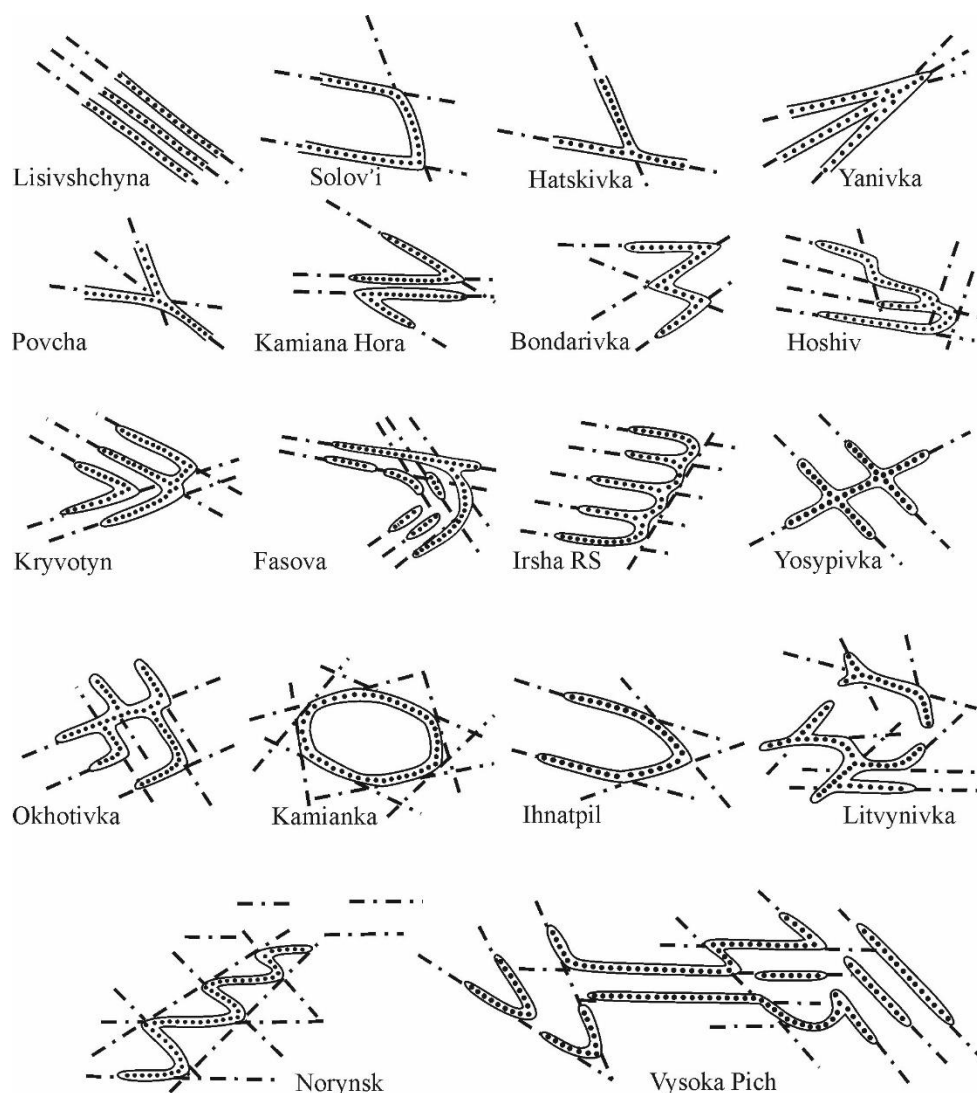


Figure 3. Correlation of linear-ridge relief forms with neotectonic faults (according to MASS).

A clear correlation between the formation of the strands and the processes of neotectonic development of block structures of the crystalline basement has been established. Strands are almost absent on large monolithic blocks composed of sediments of the same age. At the same time, they are

developed in planes on neotectonic structures, within which complex, alternating, sharply amplitude movements of blocks are observed. The largest strands of the orthogonal and diagonal azimuthal systems are confined to major tectonic zones.

These facts contradict the established views on the aeolian origin of the strands. These include their absolute straightness over a long distance, geometrically correct and complex configurations, the ring shape of the ridges, the combination of forms of different directions and configurations in one area, cases of ridge merging, the discrepancy between the directions and asymmetry of the ridges and the direction of the prevailing winds, the nature of the layering of sediments and the presence of coarse debris in them, and the absence of traces of progressive movement of the forms (figure 4).

The glacial and glaciofluvial origin of some ridges is possible in areas of moraine and moraine-zandrine plains, but outside the development of the latter, another explanation is needed. The above facts of the morphology and geological structure of the ridges and their connection with neotectonic structures allowed us to create a structural and tectonic kinematic model of their formation (figure 5).

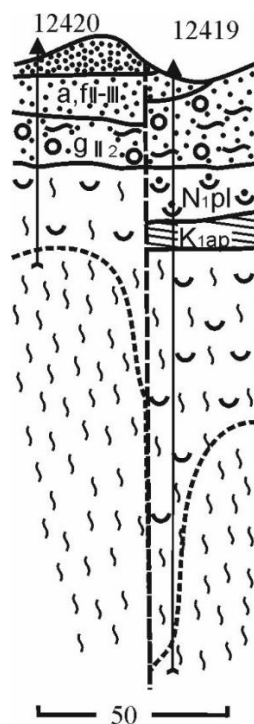


Figure 4. Structural and geological conditions for the formation of linear-ridge forms, Sushki district, Zhytomyr region (symbols in figure 1).

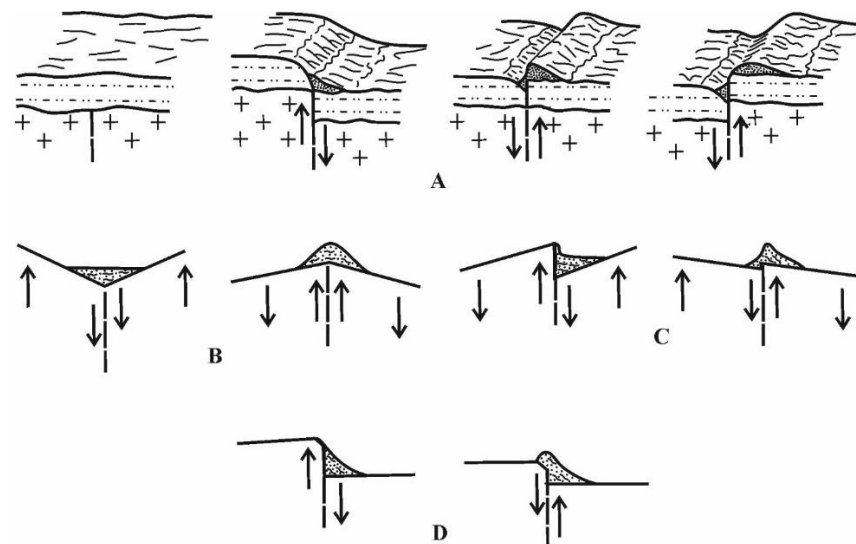


Figure 5. Kinematic models of the formation of linear belt forms under conditions of oscillatory movements of neotectonic blocks at: A – complete inversion of movements; B – opposite tilts of the block surfaces of the blocks; C – one-sided tilting of the block surfaces; D – incomplete inversion of movements.

The model analysis shows that vertical movements of the blocks relative to each other result in a ledge in the relief of the modern surface, at the foot of which a loose sediment plume will accumulate, formed as a result of the ledge destruction or introduced sediments. Changing the sign of block movements leads to the formation of a new scarp facing in the opposite direction. As a result of such inversion movements, a kind of seam of redeposited loose material forms a positive shape in the relief – a ridge along the line of neotectonic movements and overlapping it. Thus, a ridge appears in the relief as a trace of a bilateral neotectonic scarp, which consistently arises during the inversion of movements of neighboring blocks.

The model presented here is general. In specific cases, the peculiarities of the occurrence of strands depend on specific geomorphic and structural-tectonic conditions. In particular, the size and planned

configuration of neotectonic blocks, the speed and amplitude of each movement, the frequency of change of motion signs, the inclinations of block surfaces and their changes during inversion, the lithological composition and thickness of the cover rocks, and exogenous processes.

This kinematic model explains such features of strand shapes as their length, planar outlines, orientation and geometry of individual shapes, defined intervals between parallel strands, strand merging, and others. The edges of the block structures control not only the strands, but also the boundaries of other surfaces and shapes. The formation of annular and oval ridges is explained by uniform movements of the entire neotectonic block, and parabolic, semi-annular, acute-angled and rectilinear ridges by uneven or different sign movements of individual parts of a single block and with so-called "skews".

The following regularity was also established: the eastern parts of the blocks, which were located in the middle of the strand contour, were the most mobile and high-amplitude in their movements. The asymmetry in the transverse profile of the strands reflects the sequence of formation of their slopes - the less prominent slope is later. The height of the ridges is determined by the amplitudes of neotectonic oscillatory movements. The ridges are formed mainly as a result of redeposition of surface sedimentary horizons. The correctness of the presented model is confirmed by field observations, in particular, in man-made quarries for the extraction of various minerals within the PAB territory [7, 15, 16].

Lake basins. There are hundreds of large and smaller lakes within the PAB, especially in its western part (north of the runway). Over the years, researchers have proposed hypotheses regarding the formation of their hollows, including glacial, alluvial and relict, and the most popular one is karst. The main reason for the latter is the location of lakes in the areas of karst marl and chalk rocks. At the same time, there were remarks about the connection of lakes and other forms of relief in Volyn with tectonic manifestations - zones of disturbances, dislocations, rock crushing, and interference of tectonic structures (P. Tutkovskiy, O. Marinich). At the end of the 20th century, a significant amount of geological, hydromelioration, geophysical, paleogeomorphological work was carried out on the territory of the PAB, including MASS (later DRM), which confirmed the connection between landforms and tectonic structures, including lake basins.

It is noteworthy that most of the lakes are round and oval in shape, with a relatively straight shoreline without complex bends and curves that are typical of karst forms. The diameters of some lakes are hundreds of meters and even kilometers. Sometimes the lakes fill several depressions, but the outline of the forms in the outer borders of such a grouping is preserved. A similar differentiation of such areas can be seen in the underwater relief and in the relief of buried surfaces under the lakes. Some lakes with a complex morphology have characteristic transitions in the form of capes that are opposite each other, which gives the lakes a figure-of-eight appearance (lakes Luka, Mshane, Orikhovo).

Another important feature of the lake areas is the widespread development of ridges, ramparts and shaft-like elevations composed mainly of sand, which researchers often attribute to glacial or aeolian origin. The ramparts and elevations consist of individual rectilinear and arcuate ridges and isolated hillocks, which are up to 10–15 m high. The ramparts surround the lakes directly, forming a continuous ring, or are located at some distance and parallel to the lake contour.

In cross-section, their asymmetrical and steeper slopes are turned towards the lake. Systems of ridges and hills surround both large and small lakes and there is no correlation between the height of the ramparts and the size of the lakes they surround. In addition, some lakes and ridges do not form a single morphological complex.

The bands of lake basins are located in major tectonic zones in most orthogonal and northwestern strikes (these are the bands of lakes: Shatske–Turske–Kisobul, Luka–Volyanske–Skoren, Orikhove–Strybizh–Synovo). Some lakes are located at the intersection of tectonic zones of different directions and are bordered by tectonic fault systems.

The results of drilling carried out in the waters of many lakes indicate their special geological structure. For example, there are no marine Paleogene sediments under the lakes located in the area of marine Paleogene sediments. Within the glacial area of the PAB territory, there are no glacial or water-glacial deposits under the lakes either. Alluvial erosion of Paleogene and glacial sediments under the

lakes is not confirmed, since the base of the lake and lake-alluvial sediments that fill the lake basins is located 30–50 m below the base of the oldest alluvial horizons of the Prypyat River. The Paleogene and glacial sediments could not have been dissolved by karst, because it is unclear where the Paleogene quartz-glaucinite sands of siltstone and clay, which are not karst, have gone. And the bottom of lake Tukhove is underlain by Upper Proterozoic sandstones.

At the same time, the presence of glauconite in the Quaternary sediments is evidence of the erosion of Paleogene sediments. The paleogeographical conditions of the Neogene-Quaternary period in the PAB area were not favorable for the syngeneic formation of this mineral. It could only have been redeposited into the Quaternary sediments from Paleogene rocks. It is known that glauconite is rapidly destroyed in an oxidizing (slightly acidic) environment and is not transported far. Glauconite can be preserved in Quaternary sediments due to the high groundwater level, which narrows the aeration zone, and the predominance of neutral, slightly alkaline composition of natural waters due to the widespread development of carbonate rocks here. Glauconitic is more common in the foot of the Quaternary sediments, but in the areas of lakes and river valleys, both individual horizons and the entire thickness are enriched with it. In river valleys and valley depressions, the contours of glauconite-bearing rocks are ribbon-like in plan, but in lake areas their contours are elongated ellipses (lakes Bile and Ostrovske).

Very sharp fluctuations in the thickness of Upper Cretaceous and Lower Cretaceous rocks are found beneath some lakes (lakes Bile and Nobel). In our opinion, all of the described geological and geomorphological features of the lake areas can be explained by the structural and tectonic model we have developed [7]. The lakes are confined to neotectonic blocks, which in the post-Middle Quaternary are marked by anomalous mode and amplitude of tectonic movements. According to this model, the lake basin was formed in 2 stages. At the first stage, in the post-Dnipro time, against the background of differentiated amplitude and sign of movements of various neotectonic structures, some blocks were distinguished by anomalous uplift amplitudes. The processes of planar denudation and sometimes linear erosion destroyed Paleogene sediments and their fragments from previous epochs of denudation, and eroded the overlying Neogene and Quaternary sediments, including the Dnipro glaciation moraine.

At the second stage, the direction of movement of these structures was reversed and they began to sink, again anomalously in amplitude, which probably continues to this day (figure 6). Thus, in the present-day relief of Volyn Polissya, peculiar lake basins could have appeared, which are filled with lake and alluvial sediments in addition to lake sediments, since many lakes are flowing or were flowing in the past. In our opinion, the considered model of lake basin formation explains the existence of morphological complexes such as "lake basin – ridge" and "lake basin – hill" in the PBB. It does not exclude the participation of karst processes in the formation of lake basins [5].

Karst forms. As noted above, karst rocks and modern forms of karst, such as sinkholes, depressions and lake hollows, are developed on a large part of the Volyn-Podolsk plate. In addition to Upper Cretaceous carbonate rocks (chalk, marl), karst processes are facilitated by underlying fractured crystalline rocks, which produce fracture water aggressive to carbonate rocks, as well as neotectonic movements. During geological surveys, cavities up to 3–4 m in size were found in the Cretaceous rocks at a considerable depth and a peculiar "karst-depression relief" was identified [2]. Ancient karst sinkholes filled with Eocene and Oligocene sediments were uncovered by some wells, which confirm ancient karst processes in the PAB area before the transgression of the Paleogene seas.

P.A. Tutkovsky wrote about karst in this area at the beginning of the last century [18]. He pointed out the possibility of karst sinkholes formation in the Tertiary period [19]. P.A. Tutkovsky noted the facts of finding amber in lakes of karst origin [20]. Specialized prospecting for amber confirmed that its commercial deposits were confined to local ancient depressions.

The ancient karst forms were later filled with sediments and covered by younger ones. Within the PAB area, some wells recorded sharp depressions on the Cretaceous rock surface slightly inclined to the northeast, which are likely caused by buried karst forms. In some cases, carbonate rocks of the Cretaceous system are absent and Paleogene and Quaternary sediments are directly overlain by Proterozoic sandstones. The fluctuations of the Paleogene and Quaternary rocks' base in the places of karst cavities and depressions on the buried surface are 7–65 m, and sometimes reach 100 m.

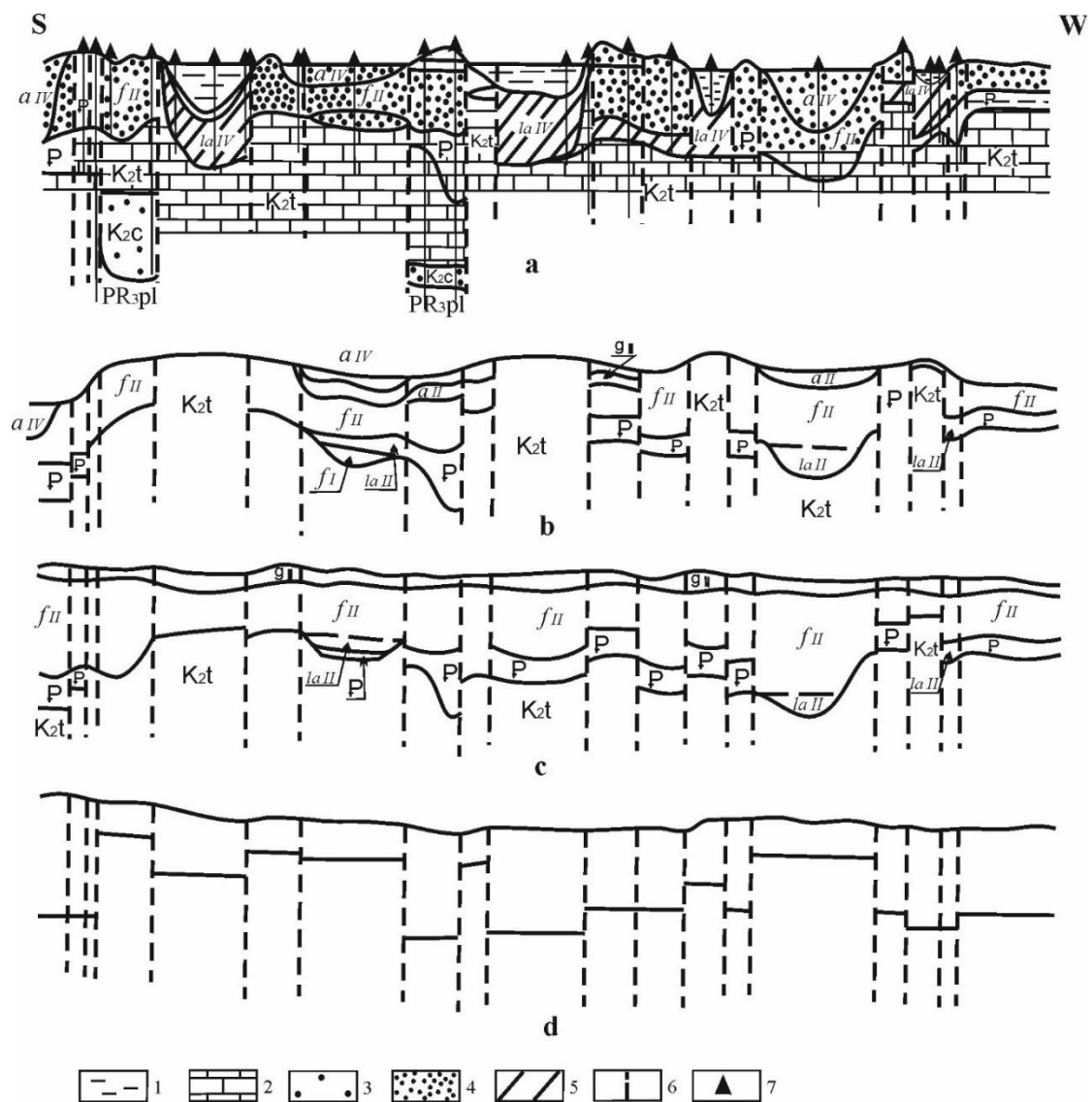


Figure 6. Structural and tectonic model of the development of the PAB lakes area (Volyn Polissya) lakes in the Paleogene-Holocene: a – end of Paleogene sediment accumulation; b – end of Middle Quaternary moraine accumulation; c – Late Quaternary time; d – modern epoch. K_{2t} – Upper Cretaceous, Turonian. Symbols to cuts: 1 – water basin, lakes, 2 – Cretaceous marl strata, 3 – sandstone, 4 – sand, 5 – loam, 6 – faults, 7 – boreholes.

4. Conclusions

The expansion of the mineral resource base of the amber industry in Ukraine is possible due to the development of the PAB. AFPS being created here is of socio-economic and environmental importance for the area, and of educational and upbringing significance for society as a whole.

The AFPS is based on the significant scientific, information and methodological potential of geological and other sciences related to the amber problem. The theoretical basis of the prospecting and exploration block of the AFPS is the concept of the AF, which allows solving the main practical task - search for AO - "traps" of alluvial amber deposits. The AF concept allows us to substantiate the genetic types of AO and to make their classification.

The morphogenetic amber traps of the PAB belong to the combined type of AF. They have been practically proven to be promising for finding amber traps. They are economically beneficial, available

for studying by relatively inexpensive methods (MASS, DRM), prospecting, exploration, and operation. The article discusses only some of them. These are hills, ridge-hills, linear-ridge accumulative forms; lake basins; karst forms. Their positions in the relief, morphology, geological structure and significant influence of structural and tectonic factors (neotectonic block structures and peculiarities of their geodynamics) on their formation are described.

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