CHAPTER «GEOLOGICAL SCIENCES»

THE "WINGED FORELAND" ABRASION-ACCUMULATIVE SYSTEMS

Oleksiy Davydov[1]
Mariya Zinchenko[2]

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Abstract. *The purpose* of the study is to conduct a deep morphogenetic analysis of the "Winged forelands" coastal systems to highlight system-wide genetic features and present the most complete scientific definition, as well as to conduct morphogenetic identification and geographical allocation of these systems. *Methodology.* The object of the study is the "Winged forelands" coastal systems. The subject of the study is the analysis of genetic features of the "Winged forelands" abrasion-accumulative systems at the present stage of development. During the study we used the following methods: logical and theoretical generalization, finding empirical dependencies, analytical and cartographic analysis. Based on the results of the study, we came to the conclusion that the natural "Winged foreland" formation refers to divergent-type abrasion-accumulating lithodynamic systems. Within their limits, oppositely directed alongshore drift flows occur with a certain periodicity and they consist of three components – the indigenous area of the coast and two accumulative forms. The specific peculiarities of the "Winged foreland" are due to the presence of a certain number of genetic features, which include: morphological, lithodynamic, hydrodynamic and evolutionary. However, the manifestation of all these features at the same time is extremely rare. Therefore, in our opinion, the presence of 2-3 features is sufficient for the formation of a specific appearance

[1] Candidate of Geographic Sciences, Associate Professor,
Head of the Department of Ecology and Geography,
Kherson State University, Ukraine
[2] Lecturer at the Department of Ecology and Geography,
Kherson State University, Ukraine

of this coastal formation. The "Winged foreland" received a fairly limited distribution, which indicates the great specificity of the conditions in their formation. The largest number of these formations is characteristic of the shores of internal seas, where genetic factors of development do not appear regularly, but with a certain interval. That is why, in our opinion, periodic changes in development conditions, which are most often manifested in the conditions of non-tidal seas, are very important for the formation of these systems. *Practical implications*. The obtained research results can be used in solving a number of theoretical problems in the development of environmental measures; developing an overall strategy for economic and recreational development of the coastal zone within the "Winged foreland" formations. Scientific novelty. In this paper, for the first time, a general classification of genetic features of abrasion-accumulative coastal systems within the study region is summarized and their correspondence to characteristics of the "Winged foreland" formation is analyzed.

1. Introduction

The coastal zone of the World Ocean is a very complex natural formation located on the border between land and ocean and is a very important link in the global lithodynamic system [4; 5; 35; 36; 43; 51]. Structurally, this natural formation consists of a set of separate sections or coastal lithodynamic systems, which are characterized by an independent regime and sediment budget [11; 15; 35; 51]. Lithodynamic systems in the coastal zone of the World Ocean are characterized by a certain variety. The most specific and at the same time the least described are the "Winged forelands" abrasion-accumulative coastal systems.

At the present stage of development of the coastal zone of the World Ocean, within its limits, anthropogenic activity intensifies, which leads to significant changes in the direction of evolution of many coastal systems. It should be noted that these changes very often are unpredictable and destructive. Considering the insignificant degree of knowledge of the "Winged forelands" formations, it is impossible to carry out activities aimed at rational nature management within them, which is why the topic of this publication is actual.

The purpose of the study is to conduct a deep morphogenetic analysis of the "Winged forelands" coastal systems to highlight system-wide genetic features

and present the most complete scientific definition, as well as to conduct morphogenetic identification and geographical allocation of these systems.

The methodological basis of this study is the English- and Russian-language publications devoted to these systems, as well as our own field studies conducted on the shores of the Black Sea and the Sea of Azov.

In this paper, we will consider the taxonomic place of the "Winged forelands" among coastal lithodynamic systems, as well as analyze the terminological definition of these formations presented earlier and propose our own. Based on an in-depth analysis of publications devoted to the "Winged forelands", we will identify the genetic characteristics of these formations, analyze their geographical allocation and identify the most famous coastal systems of this type.

2. Lithodynamic coastal systems and their diversity

Within the coastal zone of the oceans the separate large areas are distinguished, which are characterized by an independent regime and sediment budget. These areas represent unified complexly developing formations called lithodynamic systems or cells [18; 19; 35; 36; 45; 51].

In a specialized terminological reference book on marine geomorphology, the lithodynamic system is defined as a large area of the coastal zone with a sediment regime and budget that is independent of other similar areas. This concept originated due to the need to analyze the mutual influence of individual areas of the coastal zone both for research purposes and during the construction of shore protection structures that interrupt the alongshore movement of sediments. Each coastal lithodynamic system includes a sediment source, a transition zone and an accumulation area [45, p. 73].

Coastal lithodynamic systems according to the nature of the direction of sedimentation flows within their limits are divided into three groups: *abrasive, abrasion-accumulative and accumulative* [31; 35; 51].

Abrasive coastal systems are areas of the coastal zone with very active destruction processes of the surface and underwater parts. A large amount of clastic material is formed within their limits, which, due to the morphological or lithological features of the coastal zone, does not stay within it, but performs an active downward movement towards deeper areas of the nearshore slope.

Accumulative coastal systems are areas of the coastal zone within which there is a massive accumulation of coastal-marine sediments formed on the

nearshore slope. They enter the accumulation region due to the transverse or alongshore drift flow.

Abrasion-accumulative coastal systems are complex lithodynamic formations, which are most widespread in the coastal zone of the World Ocean. Structurally, within these systems, three components are distinguished: an abrasion area (supply zone), an abrasion-accumulating area (transit zone) and an accumulative area (discharge zone). For the corresponding systems, the main genetic feature is the presence in the coastal zone of an alongshore drift flow. It should be noted that in most cases, this movement of sediments appears simultaneously with the transverse.

The described coastal systems are characterized by a variety of genetic and lithodynamic features that contribute to the formation of their morphological diversity. According to the direction of coastal-marine deposits movement, abrasion-accumulative systems are divided into *convergent* and *divergent*.

Abrasion-accumulative convergent coastal systems consist of two separate abrasive areas, within which alongshore drift flows are formed, directed towards a single accumulation area, where the marine accumulative form is formed [45, p. 72].

Abrasion-accumulative divergent coastal systems are characterized by the presence of one abrasion area, within which two oppositely directed alongshore drift flows are formed. These flows form two different accumulative forms, which at the same time are elements of a unified coastal system. These coastal formations are called "Winged foreland" and they are characterized by a rather limited distribution in the coastal zone of the oceans.

Structurally, the "Winged foreland" abrasion-accumulative systems are two abrasion-accumulative pairs, within which a common supply area is allocated, usually in the form of an abrasion shore, to which two transit and discharge zones adjoining on opposite sides, having the form of accumulative forms.

These coastal systems do not have a unified scientific definition; there is no consensus on their genetic features and diversity, as well as on the place of these formations in the lithodynamic system of the coastal zone of the World Ocean. All this together contributed to the fact that the "Winged forelands" were not deservedly deprived of attention and did not have an appropriate degree of knowledge.

3. The definition of the "Winged foreland" coastal system

The definition of "Winged foreland" in the original interpretation of "Winged beheadland" was first proposed by the American scientist F. Gulliver [9, p. 213]. According to this author, the "Winged beheadland" is a specific coastal formation, which comprises a section of the indigenous coast and two accumulative forms adjacent to it from opposite sides. Alongshore movement of sediments is carried out between structural elements, mainly from the indigenous section in the direction of accumulative forms, while the direction of flows has seasonal differences.

At the beginning of the twentieth century, the English scientist Douglas Johnson gave his definition to the concept of "Winged foreland" in his fundamental work "Shore process and development" [10, p. 306]. According to Johnson, the "Winged forelands" (the "Winged headland" as interpreted by the author) are specific coastal forms that look like a cape, bounded on both sides by bays and accumulative spits. At the same time, the author believes that these landforms are formed within the originally dissected bay coast, at the stage of its youth. The abrasion of the protruding indigenous capes leads to the formation of clastic material, which is involved in the alongshore movement, and contributes to the formation of accumulative forms.

V.P. Zenkovich described the "Winged foreland" coastal formations as a special type of abrasion-accumulating systems in which one abrasion section (cape) feeds two forms on either side of itself, resulting in specific formations [31, p. 295].

The author notes that this term is used regardless of whether the spits are directed inside the coastal contour or are elongated along the same line with each other and the abraded part of the cape. At the same time V.P. Zenkovich focuses on the evolutionary aspect, according to which, the consistent restoration of development phases of this form indicates that earlier both spits were directed towards the coast and made a certain angle with the edges of the cape. The subsequent pulling of the system in one line occurs due to the abrasion of the cape and the simultaneous accumulation along the entire front of the spits; for each of them the process occurs at different times. With the simultaneous direction of the waves, only the corresponding abrasion section and spit are active, while the second pair is blocked; in the other direction of the waves, they change places [31, p. 295].

V.P. Zenkovich in his fundamental specialized work "Processes of coastal development" slightly expands the understanding of the "Winged forelands" nature, focuses on the fact that this formation is a region of interaction between two adjacent abrasion-accumulating pairs. In one direction of the waves, only the abrasion section and the corresponding spit are active; the second spit is blocked at this time. In a different direction of the waves, they change places. At the same time, both spits turn into "displaced" forms [35, p. 406].

The final definition of the "Winged foreland" coastal system was presented by V.P. Zenkovich in a specialized directory [45, p. 186]:

"Winged foreland" is a combination of an eroded indigenous cape and two spits that grow due to the transfer of destruction products on either side of it. Examples are frequent on the Drumlin shores".

It should be noted that in this reference manual [45, p. 134)] the estuarine areas of one-arm deltas, which are designated as "flanking bars" [47], are also referred to "Winged foreland" coastal systems. In our opinion, the allocation of the "Winged foreland" system in the area of the river estuary does not correspond to the initial definition of such formations, at the same time, emphasizes their lithological and morphological features.

The most general definition of the studied coastal system was presented by Schukin I.S. in the encyclopedic dictionary: "Winged foreland is a cape with spits extending from both sides – "wings" washed by the sea" [49, p. 216].

In 1982, the specialized encyclopedia "The Encyclopedia of Beaches and Coastal Environments" was edited by Maurice L. Schwartz. In this work, "Winged forelands" are considered not as a natural system, but as one of the specific types of accumulative coastal forms – spits, which develop in the conditions of existence of divergent sediment flows [19, p. 790].

Thus, for more than a century of coastal science development, there is no universally accepted definition of this coastal system. That is why, on the basis of the analysis of literary, cartographic and general geographic materials, as well as our own field studies, we presented our own definition of this system.

"Winged foreland" is an abrasion-accumulative coastal system that has divergent features, within which three morphological components are identified, interconnected by alongshore sediments flows [30, p. 127].

4. Genetic features of the "Winged foreland" coastal system

Based on an analysis of the works of English-speaking [6; 9; 16; 19] and Russian-speaking scientists [25; 31; 33; 34; 39; 40; 43; 45; 51], we interpreted the generalized genetic features of the "Winged forelands" coastal systems. In our opinion, these features include: morphological, lithodynamic, hydrodynamic and evolutionary.

Morphological feature. According to the generally accepted opinion, three morphological elements are distinguished within the "Winged foreland" coastal system: the abrasive indigenous coast and two accumulative forms located on either side of it. These accumulative forms are in most cases free, that is to say extended towards the sea. Thanks to this feature, F. Gulliver applied the term "Winged headland" ("Winged foreland") to this formation. It should be noted that this feature is typical for absolutely all formations of this type.

Lithodynamic feature. The indigenous area of the coast located in the central part of the system is actively destroyed, retreats and supplies the accumulative formations adjoining it with clastic material. However, in our opinion, the alongshore drift flows that begin within the divergence zone and are directed in opposite directions are a more important system-forming factor, thereby forming morphological features of the "Winged foreland" coastal system. This feature is inherent for most of these formations, but within some it is not clearly expressed or has a seasonal character.

Hydrodynamic feature. Within the studied systems, two adjacent abrasion-accumulative systems interact, which develop in a reverse mode, depending on the characteristics of the waves. The formation of a certain wave between the indigenous abrasion area and one of the accumulative forms leads to activation of the alongshore drift flow, while the other form does not receive the supply, it remains blocked. With the formation of another direction wave, the accumulative formations change places. It is this feature that determines the existence of two accumulative forms within the studied system.

Evolutionary feature. In most of the earlier descriptions, the "Winged forelands" coastal systems are considered as an integral part of the evolution of a dismembered bay coast. Moreover, their formation occurs in the early stages of development of this coast, and eventually leads to its alignment and transformation into an abrasive-aligned.

The distinguished genetic features of the studied coastal system made it possible to analyze the diversity of abrasion-accumulative systems and to interpret "Winged foreland" among them according to morphological characteristics and to evaluate their geographical distribution [8].

5. Geographical allocation of "Winged forelands" coastal systems

The "Winged forelands" coastal systems were originally identified and described within the oceanic shores on the Atlantic coast of North America. However, they received the greatest distribution within the internal seas of Eurasia, within which there are no tidal occurrences; these include the Sea of Azov, the Black, the Baltic and the Caspian seas [8; 9]. Considering that oceanic and marine formations are formed under different hydrological situations, we decided to focus on coastal systems of internal seas, where genetic features can be analyzed using different examples.

Within the Black Sea coastal zone, systems morphologically similar to the "Winged forelands" are located exclusively in the shallow northwestern part (Figure 1). The largest coastal system of this type is *Tendra-Dzharylgach,* its total length is about 130 km, of which the indigenous area or "headland" is 22 km, the Tendra spit is 65 km, and the Dzharylgach spit is 42 km. Morphogenetically, this formation is a coastal bar that has experienced displacement and transformation [29; 38].

The Kinburnska-Pokrovska-Dovgiy coastal system has a length of about 35 km, of which "headland" is 12 km, the Kinburnska Spit is 10 km, the Pokrovska Spit is 6 km and the complex system of the island bar and the Krugliy and Dovgiy islands are about 7 km. The genesis of this "Winged foreland" is also associated with the displacement and transformation of the coastal bar [34; 54].

The Lebedina-Vustrichna coastal system has a total length of 6.1 km, of which the indigenous protrusion occupies 4.3 km, the Lebedina Spit is about 0.34 km, and the Vustrichna Spit is 1.5 km. Morphogenetically, the accumulative forms of the system are spits, the formation of which is directly dependent on the biogenic factor.

The total length of the *Burnaska-Budatska coastal system* is about 55 km, of which the "headland" is 30 km, the Burnaska barrier beach is 6 km and the Budatska barrier beach is 17 km. Genetically, this system is also an adjoining and transformed coastal bar [25; 34; 55].

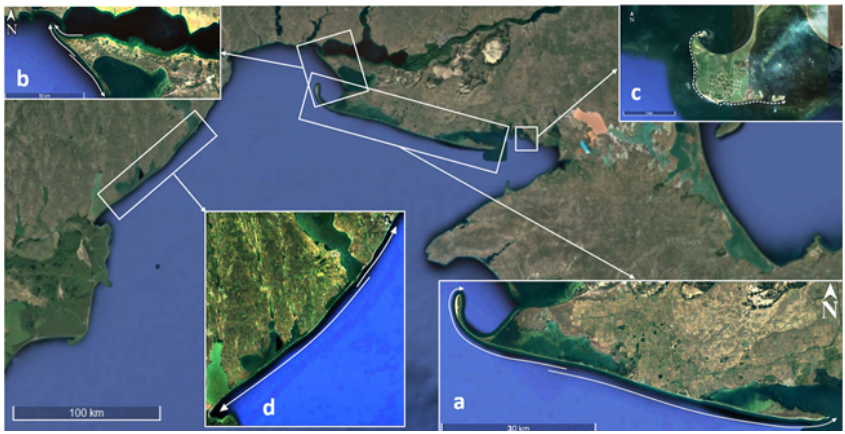

Figure 1. The Geographical location of the "Winged forelands" coastal systems within the coastal zone of the northwestern part of the Black Sea. The letters on the map mark the coastal systems: a – Tendra-Dzharylgach; b – Kinburnska-Pokrovska-Dovgiy; c – Lebedina-Vustrichna; d – Burnaska-Budatska (created based on the Google Earth resource)

The Dolgaya-Kamyshevatskaya is the only "winged foreland" within the coastal zone of the Sea of Azov located in the eastern part, in the region of the Yeysk Peninsula (Figure 2, a). The length of the system is about 53 km, of which the "headland" occupies about 30 km, the Dolgaya Spit is 17 km, and the Kamyshevatskaya Spit is 6 km. The genesis and evolution of the system is associated with the transformation of the coastal bar and the formation of arrow-shaped spit and spit within its termination [12; 35; 44].

The Curonian-Baltic coastal system is located in the southeastern part of the Baltic Sea (Figure 2, b). Its total length is about 220 km, of which the "headland" occupies about 54 km, the Curonian Spit is 98 km, and the Baltic (Vistula) Spit is 65 km. Genetically, this system is also a coastal bar that has shifted and transformed [3; 21; 22]. The indigenous cusp is composed of glacial rocks, and accumulative forms consist of alluvial and fluvioglacial sands [2; 17].

The Cheleken "winged foreland" is located in the coastal zone of the Cheleken Peninsula, in the southeastern part of the Caspian Sea (Figure 2, c).

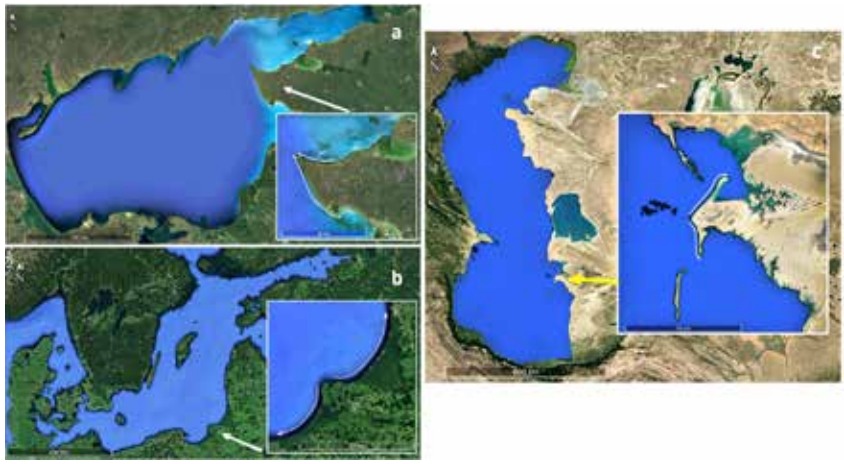

Figure 2. The geographical location of the "Winged forelands" coastal systems: a) Dolgaya-Kamyshevatskaya, eastern part of the Sea of Azov; b) Curonian-Baltic, southeastern part of the Baltic Sea; c) Cheleken, the southeastern part of the Caspian Sea

The total length of the system is about 62 km, of which the indigenous areas are 25 km, the North Cheleken Spit is 20 km, and the South Cheleken Spit is 17 km. Morphogenetically, this coastal system is also a coastal bar [32; 35; 40; 41].

6. Morphogenetic analysis of the "Winged forelands" coastal systems

Having determined the geographical allocation of coastal systems, which resemble the "Winged forelands" in their morphological appearance, we have to analyze their morphogenetic features. To do this, we will study the largest formations of this type for their correspondence to the genetic characteristics of the "Winged foreland" abrasion-accumulative coastal systems.

The Tendra-Dzharylgach coastal system is the largest coastal system of this type within the Black Sea. The central place in the system is occupied by the continental protrusion or "headland", which is formed by two acclivous anticlinal folds composed of clay and loess-clay rocks [7; 46; 56]. This protrusion genetically represents an alluvial overbottom terrace, which breaks off towards the sea with an abrasion cliff up to 2 m high. On the

opposite sides, two free accumulative forms adjoin the "headland" – the Tendra Spit (in the west) and the Dzharylgach Spit (in the east) (Figure 3, a).

The accumulative forms of this system are characterized by narrowed basal areas and widened distal areas, which is known to be an indicator of the entire system pulling in line and the manifestation of accumulation only near the extremities [35].

Figure 3. Morphogenetic conditions of the Tendra-Dzharylgach coastal system: a) morphological structure; b) lithodynamic features; c) structure of the wind regime (developed on the basis of the Google Earth resource)

Morphologically this coastal system is a typical "Winged foreland", however, lithodynamic conditions have certain differences. So, the feeding of accumulative forms is carried out not due to the destruction of the abrasion area, but is the result of erosion of underwater forms and the income of a large amount of organic material [35; 38; 56]. At the same time within the system the alongshore movement of sediments with certain seasonal differences appears and there is a divergence zone located on the nearshore slope in the central part of the Tendra Spit (Figure 3, b). From this zone, the alongshore flows diverge in opposite directions, heading to the distal extremities of the Tendra and Dzharylgach spits. It should be noted that the presence of a divergence zone is the most important lithodynamic feature of the "Winged forelands".

An analysis of the structure of the wind-wave regime indicates the dominance of waves of western, southwestern and eastern exposure during the year (Figure 3, c) [27]. Comparing the orientation of the coastal system and the dominant wave directions, it should be noted that the

hydrodynamic conditions correspond to the genetic characteristics of the "Winged foreland" coastal systems. That is why, from our point of view, the Tendra-Dzharylgach coastal system is an indicative formation of this type, as evidenced by two symmetrical accumulative forms [29].

From the point of view of the evolutionary feature, the elongation of the system in one line fits well into the alignment scheme of a complex bay coast, which is at the maturity stage.

An analysis of the Tendra-Dzharylgach coastal system, from the point of view of its correspondence to the genetic characteristics of "Winged foreland" formations indicates that this system is characterized by three of the four features. A lithodynamic characteristics also takes place, but with small specific features.

The Kinburnska-Pokrovska-Dovgiy coastal system occupies the western end of the Kinburnskiy Peninsula (Figure 4). Unlike other coastal systems of this type, the central place in it is occupied by the sandy protrusion of the Kinburnskiy Peninsula, which is periodically eroded.

Figure 4. Morphogenetic conditions of the Kinburnska-Pokrovska-Dovgiy coastal system: a) morphological structure; b) lithodynamic features; c) structure of the wind regime (developed on the basis of the Google Earth resource)

The Kinburnska Spit occupies the northwestern part of the system, and a complex formation of different ages represented by a relict branch (Pokrovska Spit, Krugliy and Dovgiy islands) and a modern branch (Sukha Spit and Barrier Island) locates in the southeast. Morphologically, this formation is "Winged foreland" [30].

An analysis of the lithodynamic conditions of this system indicates the dominance of bottom feeding and, as a consequence, the transverse sediments flow. However, the morphological features of the coastal zone of accumulative forms indicate a periodic manifestation of alongshore drift flows, which are reversible. During field studies, it was found that this system is characterized by a divergence zone, which is located in the region of the basal part of the Kinburnska Spit, but during severe storms it can cover the entire frontal part of the protrusion.

It should be noted that the lithodynamic conditions of the system are complicated by constant or seasonal alongshore drift flows from the Dnieper-Bug estuary and the Yagorlytska Bay. That is why the distal part of the Kinburnska Spit is a convergence zone or lithodynamic site, within which two different sediment flows are unloaded. In view of this lithodynamic situation, the Kinburnska Spit is morphogenetically an arrow-shaped spit [35; 39; 54].

The area of the relict branch of the system, which includes the Pokrovska spit (Pokrovskiy peninsula [39]), and the Krugliy and Dovgiy islands that are genetically unified with it, also previously represented a convergence zone. However, our field studies showed that there is no active interaction of alongshore drift flows in this area at the present stage.

The area of the modern branch of the system, which includes the Sukha Spit (a new generation of the Pokrovska Spit) and the Barrier Island, is an area of active unloading of both transverse and alongshore drift flow.

Accordingly, lithodynamically, the Kinburnska-Pokrovska-Dovgiy coastal system is a very specific formation, certain features of which are identical to the "Winged forelands". However, the lithodynamic situation in the system as a whole is more complex, due to the presence of a convergence zone and active bottom feeding.

An analysis of the hydrodynamic conditions in the region of the northwestern part of the Black Sea [27] (Figure 3, c) indicates the dominance of waves of the west and southwest direction, which in principle contributes to the formation of the morphological appearance of the coastal systems "Winged forelands".

A paleogeographic analysis of the area of the Kinburnska-Pokrovska-Dovgiy coastal system indicates that the formation of this system is not the result of alignment of the abrasive bay shore, but is the result of the

adjoining of the coastal bar that came out from under the water to the protrusion of the Kinburnskiy Peninsula [39].

A general analysis of the Kinburnska-Pokrovska-Dovgiy coastal system, from the position of its correspondence to the genetic features of the "Winged foreland" formations, indicates that the two characteristics (morphological and hydrodynamic) are strictly correspond, the lithodynamic feature is characterized by certain specific peculiarities, and the evolutionary feature does not correspond.

The Lebedina-Vustrichna coastal system occupies the front part of the Girkiy Kut Peninsula (Khorly). Morphologically, the peninsula is not a high coastal plateau, saddle-shaped, composed of clay and loamy rocks. The central place within it is occupied by a flat elevation, elongated from north to south, with absolute heights of about 7 m. In the direction to the coast the heights decrease to 3-6 m, and within individual valleys (cloughs) up to 0.5 m [34].

Accumulative forms adjoin the peninsula from opposite sides: the Lebedina Spit is in the north-west and the Vustrichna Spit is in the east (Figure 5). The morphological appearance of the system corresponds to the genetic feature of the "Winged forelands".

Figure 5. Morphogenetic conditions of the Lebedina-Vustrichna coastal system: a) morphological structure; b) lithodynamic features; c) structure of the wind regime (developed on the basis of the Google Earth resource)

The lithological analysis of the accumulative forms of this system indicates a clear dominance of sediments of biogenic genesis and the presence

in their composition of a large number of sediments of the "non-wave field". It should be noted that among the biogenic sediments the plant residues dominate in the form of various phytogenic relief forms. These relief forms also serve as a reservoir of silty, clay and detrital sediments.

Within the coastal zone of the frontal part and accumulative forms, there are only local traces of sediment movement. During field studies, only the conditional presence of a divergence zone was revealed. That is why according to the lithodynamic characteristic this system does not correspond to the "Winged foreland".

An analysis of the hydrodynamic conditions of the region of the Girkiy Kut Peninsula indicates the important relief-forming significance of the waves of the west and south-west direction [27]. The coordinated location of the accumulative forms, in relation to the dominant waves, emphasizes that it is the hydrodynamic factor that determines the specific appearance of the system.

The appearance of the peninsula and the adjacent areas indicates a significant dissection of the coastline, and the formation of a shallow bay coast in the region. Under such conditions, the active destruction of the "headlands" and the formation of accumulative forms on the periphery of the indigenous protrusions indicate an alignment of the coastline. However, this alignment occurs under conditions of a clear deficit of "wave field" sediments, which is why this process is very slow. Accordingly, the Lebedina-Vustrichna coastal system evolutionarily corresponds to the "Winged forelands" coastal systems.

A general analysis of the Lebedina-Vustrichna coastal system for its correspondence to the genetic features of the "Winged foreland" formations indicates that the three features (morphological, hydrodynamic and evolutionary) are strictly correspond, and the lithodynamic sign has no characteristic features of the "Winged forelands".

The Burnaska-Budatska coastal system is located on a coastal segment between the estuarine areas of the Dniester and Danube rivers [25; 34; 52]. This formation is formed around the protrusion of the abrasive indigenous coast, which is located between the localities Kurortne and Lebedivka. The Burnaskiy bar adjoins the corresponding "headland" in the south-west, and the bar of the Budatskiy estuary in the north-east (Figure 6, a).

Lithological analysis showed that clay, loamy and loess-clayey rocks dominate within the "headland" system, and sand-shell deposits are typical for

accumulative forms. Such a distribution of rocks indicates the dominance of bottom feeding of accumulative forms, followed by alongshore transport [55].

Figure 6. Morphogenetic conditions of the Burnaska-Budatska coastal system: a) morphological structure; b) lithodynamic features; c) structure of the wind regime (developed on the basis of the Google Earth resource)

Within the described system, for most of the year, a unidirectional alongshore drift flow to the Jibrieni bay appears. Periodically, in the warm season of the year, a flow directed towards the Odessa Gulf is formed in the area of the Budatskiy bar, which confirms the development of one of the divergence zone variants within this system [33; 55]. Accordingly, this coastal system is not fully, but corresponds to the lithodynamic feature of the "Winged forelands".

According to the structure of the wind regime, significant seasonal differences in the direction of the wind are appeared within the Burnaska-Budatska coastal system, which in principle leads to a reverse regime of sediment displacement [27]. Therefore, this coastal system belongs to the "Winged foreland" according to the hydrodynamic feature.

Evolutionarily, the modern morphological appearance of the Burnaska-Budatska coastal system is the result of alignment of the dissected bay coast by joining the coastal bar. Subsequently, this coastal bar was transformed by the alongshore drift flows. The modern narrowed character of the bars indicates the dominance of sediment transport within their limits without a general tendency to accumulation [35].

A general analysis of the Burnaska-Budatska system gives us reason to say that at least three genetic features of the "Winged forelands" coastal systems are inherent of this formation. Therefore, the described abrasion-accumulative system refers to formations of this kind; however, its genetic features are characterized by great specificity.

The Dolgaya-Kamyshevatskaya coastal system is an example of an abrasion-accumulative system, which by its characteristics refers to formations of the "Winged forelands" type. The pivotal place within the system is occupied by the abrasive clay protrusion of the Yeysk Peninsula. In the northwest the Dolgaya Spit adjoins it, and in the southeast – the Kamyshevatskaya Spit (Figure 7, a) [13; 35; 44]. According to morphological feature this coastal system belongs to the "Winged foreland".

Figure 7. Morphogenetic conditions of the Dolgaya-Kamyshevatskaya coastal system: a) morphological structure; b) lithodynamic features; c) structure of the wind regime (developed on the basis of the Google Earth resource)

A lithological analysis of the morphological elements of this system indicates that the indigenous land protrusion ("headland") is composed of clay rocks, while the accumulative forms consist of sandy rocks of biogenic origin, shells and detritus [50]. Consequently, the system is powered from the nearshore slope, from where the clastic material enters the coastal zone, and alongshore flows carry it in the direction of the distal parts of the Dolgaya and Kamyshevatskaya spits. That is why the region of the clay protru-

sion should be considered as a divergence zone, which, depending on the waves, can move along its entire frontal part (Figure 7, b).

It should be noted that morphogenetically the Dolgaya Spit is an arrow-shaped spit and it is also a convergence zone, and the accumulative Kamyshevatskaya form is a typical spit [35]. Accordingly, the Dolgaya-Kamyshevatskaya coastal system corresponds to the "Winged foreland" coastal systems lithodynamically.

In the structure of the wind regime, over the region of the eastern part of the Sea of Azov, winds of the west and south-west direction dominate [26]. Winds of this direction cause similar waves, which can induce reverse movements of sediment flows. Therefore, according to the hydrodynamic characteristic, the Dolgaya-Kamyshevatskaya coastal system corresponds to the "Winged forelands" abrasion-accumulative systems.

Evolutionarily, based on the morphology and morphometry of the accumulative forms, the Dolgaya-Kamyshevatskaya coastal system is a bay coast at the youth stage, which is aligned. Accordingly, this coastal system corresponds to all genetic features and is a classic example of the "Winged foreland".

The Curonian-Baltic coastal system is the largest abrasion-accumulative system of non-tidal seas, which according to morphological characteristics refers to the "Winged forelands". The central part of the system is occupied by the ledge of the Sambian Peninsula, which is adjoined with two spits from opposite sides: the Curonian and Baltic (Vistula) spits (Figure 8, a) [3; 22; 28].

The Sambian Peninsula is a protrusion of the indigenous coast, composed of glacial and fluvioglacial deposits [1; 20]. The accumulative forms adjoining the peninsula are composed of sand-pebble rocks of alluvial, fluvioglacial and marine genesis [1; 2; 17; 23]. Morphogenetically, both accumulative forms are complex coastal bars, which include areas formed as a result of the actions of alongshore drift flows, as well as areas of coastal plains partially flooded during marine transgressions (Badiukova, 2007).

R.Ya. Knaps [24; 37] identified the alongshore sediment movement within the southeastern part of the Baltic Sea, directed from the Sambian Peninsula to the Kolkasrags Cape, according to the lithodynamic characteristic. At the same time flow directed to the south of the peninsula, the author considered not clearly defined.

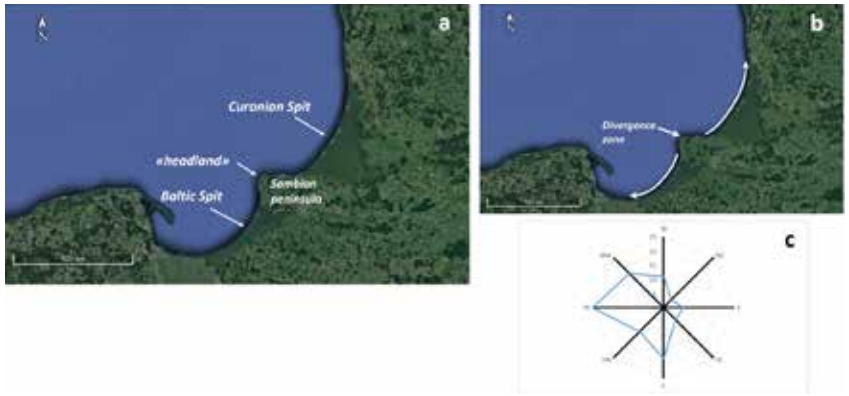

Figure 8. Morphogenetic conditions of the Curonian-Baltic coastal system: a) morphological structure; b) lithodynamic features; c) structure of the wind regime (developed on the basis of the Google Earth resource)

Over many years of research and subsequent calculations, A.N. Babakov [1] came to the conclusion that the unified directed sediment flows do not exist within the entire southeastern coast of the Baltic Sea. Instead, several local multidirectional flows are characteristic of this coastal system. However, there is no doubt that the Sambian Peninsula is a zone of divergence. That is why the Curonian-Baltic coastal system corresponds to the genetic feature of the "Winged forelands".

Analysis of the hydrodynamic factor indicates the dominance of winds and waves of the western, northwestern and southwestern exposure [48]. These wave processes perform a morphogenetic function, determining the directivity of the alongshore drift flows. Therefore, this coastal system corresponds to the hydrodynamic feature of the "Winged forelands".

The evolutionary features of the coast of this region of the Baltic Sea do not quite fit into the concept of the bay coast aligning. This is due to a shift of the accumulative forms in the direction of the mainland coast, which does not quite contribute to the theory of alignment of this type coasts [1; 3; 22].

Accordingly, this coastal system corresponds to three of the four "Winged foreland" genetic characters and is a formation of this type.

Cheleken "Winged foreland" coastal system. The corresponding system is geographically located within the frontal part of the Cheleken Peninsula (Fig. 9). Most of this protrusion is occupied by the denudation surface of the Chokrak highland, which breaks off towards the sea with a series of abrasion terraces. Structurally, this formation is the arched part of the brachianticline system [42; 46].

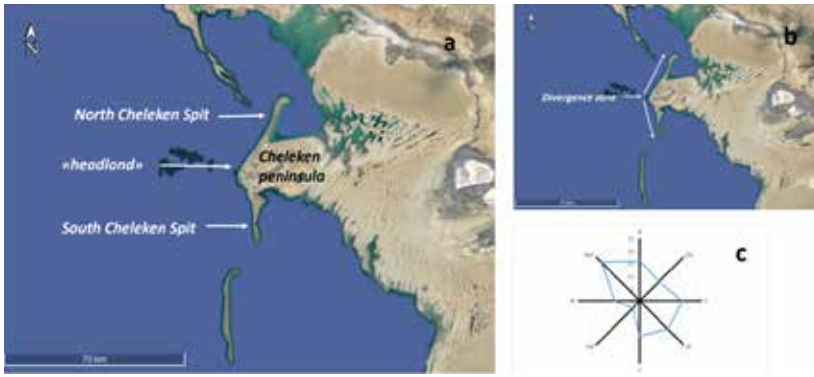

Figure 9. Morphogenetic conditions of the Cheleken coastal system: a) morphological structure; b) lithodynamic features; c) structure of the wind regime (developed on the basis of the Google Earth resource)

Accumulative forms known as the South Cheleken and North Cheleken Spits are adjacent to the peninsula from opposite sides (Figure 9 a). Morphologically, these formations are free forms, extended towards the sea and separating shallow bays from the sea. The accumulative forms that make up this system are characterized by similar morphological features: they widen to the distal part and narrow towards the basal. This similarity indicates that within the system, accumulation processes are manifested only in the area of the spits' distal, while in the basal areas the narrow parts of these forms are eroded and retreated simultaneously with the cliff. That is why it was concluded that the evolution of "Winged forelands" occurs in the direction of aligning the entire system in one line, which is an important theoretical justification of the evolutionary feature of the studied abrasion-accumulative systems [35, p. 406].

According to paleogeographic studies of the coastal zone of the Caspian Sea, the described accumulative forms are a coastal bar that adjoins the shore indigenous protrusion [14; 40]. This conclusion was made on the basis of lithological analysis of spits, according to which they are composed of sands of oolitic and biogenic genesis, with very little admixture of abrasion material [14; 42].

Accordingly, lithodynamically these accumulative formations do not feed on "headland" abrasion, since the nearshore slope is the main source of sediment. However, the distals' widened areas of both spits indicate that within the system the alongshore flows have important genetic significance simultaneously with transverse sediment transport. The symmetrical location of the spits indicates the presence of a divergence zone, which is located on the nearshore slope and is due to differences in the structure of the wave regime [40]. That is why this coastal system corresponds to the lithodynamic feature of the "Winged forelands".

An analysis of the hydrodynamic conditions in the region of the southeastern coast of the Caspian Sea indicates a dominant position of the waves of north-west and north directions at the present stage [40; 42]. Under such conditions, a symmetrical location of the accumulative forms is not possible. That is why, within this system, we cannot find confirmation of the hydrodynamic genetic feature of the "Winged forelands".

An analysis of the evolutionary feature of the Cheleken coastal system, which is based on the deviation angle of the accumulative forms relative to the shore indigenous protrusion, indicates the initial stage of alignment of the complex bay coast in this area. However, a more accurate interpretation of the evolution of this system requires additional researches.

7. Conclusions

Based on the results of the study, we came to the following conclusions:

1. The natural "Winged foreland" formation refers to divergent-type abrasion-accumulating lithodynamic systems. Within their limits, oppositely directed alongshore drift flows occur with a certain periodicity and they consist of three components – the indigenous area of the coast and two accumulative forms.

2. The specific peculiarities of the "Winged foreland" are due to the presence of a certain number of genetic features, which include: morphological,

lithodynamic, hydrodynamic and evolutionary. However, the manifestation of all these features at the same time is extremely rare. Therefore, in our opinion, the presence of 2-3 features is sufficient for the formation of a specific appearance of this coastal formation.

3. The "Winged foreland" received a fairly limited distribution, which indicates the great specificity of the conditions in their formation. The largest number of these formations is characteristic of the shores of internal seas, where genetic factors of development do not appear regularly, but with a certain interval. That is why, in our opinion, periodic changes in development conditions, which are most often manifested in the conditions of non-tidal seas, are very important for the formation of these systems.

4. To conduct the most complete morphogenetic analysis of the "Winged foreland", we plan to study in detail each coastal system of this type, with an emphasis on field research. In this case, emphasis will be placed on the study of hydrodynamic, lithodynamic and paleogeographic conditions.

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