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Vetrovoy isthmus of iturup island – holocene strait

V V Afanas'ev¹, E I Ignatov², A V Uba¹, N N Dunaev³, I O Leontiev³ and
A O Gorbunov¹

¹Institute of Marine Geology and Geophysics Far Eastern Branch of Russian Academy of Science, Nauki st., 1B, Yuzhno-Sakhalinsk, 693022, Russia

²Lomonosov Moscow State University, Moscow, Russia

³Shirshov Institute of Oceanology, RAS, Moscow, Russia

E-mail: vvasand@mail.ru

Abstract. Explosive volcanism is equally important as the features of neotectonic and modern movements for the development of the Kurile Islands coast, as it led to the afflux of hundreds of millions of cubic meters of pumicepyroclastic material and tephra into the wave processing zone of coastal zones of the Pleistocene-Holocene. Morphometric, georadar and paleogeographic studies of the coastal-sea relief of Iturup Island allowed to determine several levels of marine terraces in the pyroclastic sediments of the Late Pleistocene-Holocene, and also the presence of a buried sea strait that existed at least in the middle Holocene. Taking into account the values of deformation of the terrace levels, the depth of the strait was 10–15 meters. Volcanic-tectonic deformations connected with eruptions near the central part of the Vetrovoy Isthmus led to the collapse of pumice packs at the section basement of the sea coastal ledge with a layer of beach material on the roof (LU-9223-6320 ± 100, cal. Year BP). Thus, in the mid-late Holocene, after the sea level was risen to the nowadays levels, at least two more pyroclastic series were deposited, the last of which one is dated 1050 ± 70 cal. BP – LU-8685.

1. Introduction

The large-scale caldera-forming volcanic eruptions had an important value for the development of the Kuril Island arc. sea coasts; they caused by the arrival of millions of cubic meters of pumice-pyroclastic material and tephra in the late Neo-Pleistocene-Holocene wave processing zone. In the late Neo-Pleistocene-Holocene in Iturup Island 450 km³ of predominantly dacite pyroclastics were erupted during formation of four large collapse calderas, according to evaluation of I. V. Melekestsev [1]. The formation of the subaerial Vetrovoy isthmus is explained by the accumulation of such material during the strong explosive caldera-forming eruptions in the shallow strait between the neighboring islands [2].

The modern geomorphological isthmus outlook is associated with the subsequent wave and aeolian pyroclastic processing with the concomitant appearance of marine and lagoon terraces [3]. Cartometric and morphometric study of the coastal-marine topography forms of Vetrovoy isthmus and cross-border regions allowed to determine several abrasion and abrasion-accumulative terraced levels in the pyroclastic deposits of the late Neo-Pleistocene-Holocene. In addition, on the abrasion-accumulative surface with a 10-20 meters height of the Vetrovoy isthmus, crest-looking ridges up to 50 meters, oriented in the north-eastern direction are clearly distinguished, they are the barrier forms of the mouth of the strait (Figure 1), redeposited by wind.

In the presented work the problem of existence of the strait separating the southern and northern part of Iturup Island in the Middle - Late Holocene is considered from the coastal geomorphology position.



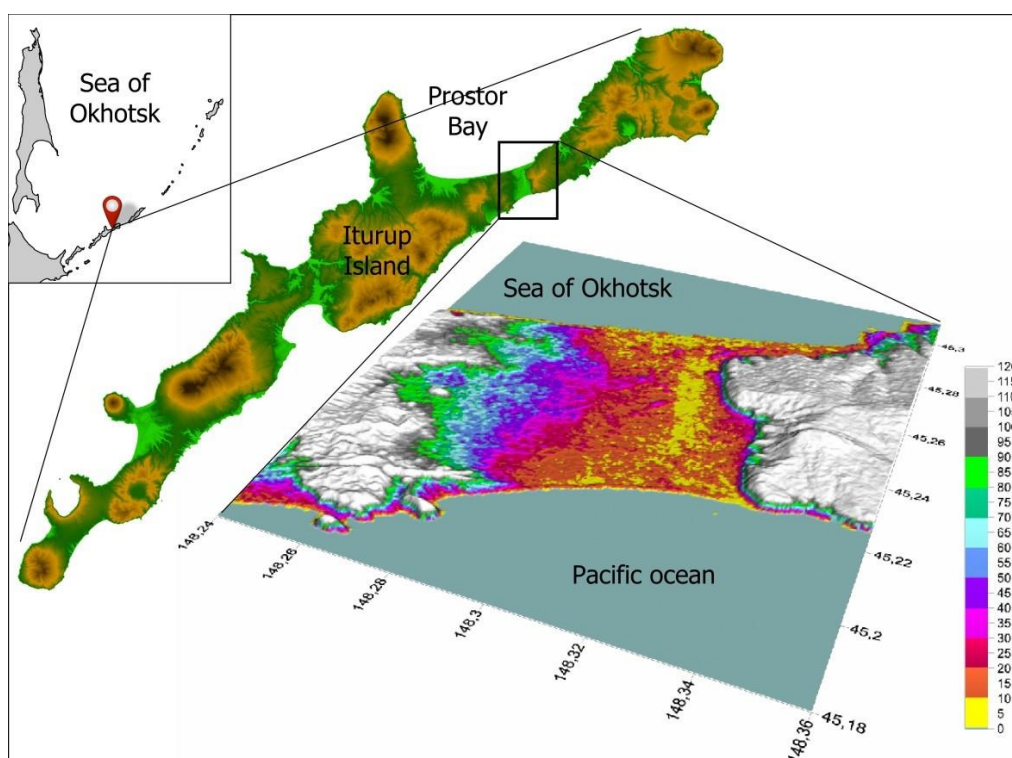


Figure 1. Overview scheme of the research area. Vetrovoy Isthmus - morphometric map (Aster Global Digital Elevation Model (GDEM V2)).

2. Overview of the problem

Nowadays it is regarded that the paroxysm of Late Pleistocene explosive volcanism was more powerful and prolonged than the Early Holocene one [4]. So in Iturup Island, the formation of pumice deposits due to great underwater caldera in Prostor Gulf. According to C14 dating of peat bog underlying pumice-pyroclastic cover in the area of Vetrovoy Isthmus in the Iturup Island it was happened 38000-39000 years ago (GIN - 7092) [5]. In Kunashir Island during this period, Mendelev and Golovnin calderas were formed correspondingly about 39000-40000 years ago (GIN-124a, 124b) and 38000-39000 years ago (GIN-581) [6]. The dates were obtained by the specimens of peat underlying pyroclastic deposits. It is assumed that these calderas are associated with the releasing of about 75 km³ (110 x 10⁹ t) of andesite-dacite pyroclastics. At the boundary between Late Pleistocene and Holocene at least two large eruptions of the Lion's Past volcano in Iturup Island were determined [7]. These eruptions are associated with the releasing of about 170 km³ of pumice of dacite composition. The presence of two complexes of pyroclastic deposits with age 12300 — 13000 l. n. (Lu - 7268, Lu - 7269, Lu - 7271) is confirmed by later studies [8].

The character of tectonic movements and volcanic-tectonic deformations is equally important condition of relief formation together with the peculiarities of regional sedimentation. The absence of genesis substantiation of alluvial terrace surfaces, that are allocated only due to the geomorphological characteristics, was driven to a considerable ambiguity of opinions and interpretations of very important problems of allocation and correlation of ancient shorelines under the study of sea coasts [9-11].

There were undertaken many attempts to isolate the Late Pleistocene raised marine and coastal-marine complexes on the coast of the Large Kuril arc. In the most defensible by factual material work Karginsky ancient shore is found only on the coast of Kunashir Island and Iturup Island and its height increases from the south to the north [12]. Height of the marine terraces in Iturup changes in the range of 10-60 m. In the opinion of P. A. Kaplin, coastal accumulative forms of this age are at a depth from 20 to 40 m, and the age and origin of Late Pleistocene terrace-looking levels on the coast of the islands were determined incorrectly [13].

The stratigraphy, genesis and chronology of the Holocene deposits of Iturup Island are also poorly studied, and based mainly on the C14 series of dates from the deposits on the coast of Kasatka Bay and Olga Bay [12]. Three transgressive phases of sedimentation which are comparable to the Atlantic, subboreal and sub-Atlantic periods with the maximum sea level rise up to 3.5 m above the recent one in the Atlantic were identified at paleogeographic study of the sections at the mouth of the Kurilka River [14]. As for the number of phases, this complies with the three Holocene rhythms of coastal-marine sedimentation which were determined earlier for the Far Eastern seas shores [15]. However, the conclusions concerned Aeolian sedimentation during periods of sea level decline based on the study of the estuarine parts of rivers cannot be extended to areas where the dunes formation is connected with the flow of sediments to the coastal zone under the increased coastal erosion as a result of sea level rise.

3. Results

As a result of field researches of 2017-2018, the volcanic-tectonic dislocations with 2-3 m layer of beach material in their roof were found in the coastal ledge on the south-western boundary of the Okhotsk sea coast of the Vetrovoy Isthmus, formed with pumice pyroclastic (Figure 2).



Figure 2. Sub-vertically stratified layers of pumice-pyroclastic deposits with interlayer of sea beach sediments in the coastal ledge on the south-western boundary of the Okhotsk sea coast of Vetrovoy Isthmus.

The angles of incidence of layers reach 80° under azimuths of falling towards the middle part of Vetrovoy Isthmus that is probably connected with their collapse as a result of an eruption near the isthmus central part, where the ruins of a large caldera could be found. The shell material from the beach sediments ^{14}C dates ranges between cal 6220-6420.BP (Lu-9223) and 7550-7690 cal.BP (Lu 9241) allows to believe these dislocations to date from the Middle Holocene during the period of maximum sea level rise.

The layers of 40-70 m thick are overlaid by pumice pyroclastics, in the upper part of which a soil horizon is observed along the erosion cuttings up to 8 m of depth, the aeolian-ash deposits with a thickness up to 5-7 meters are above this horizon. Soils formed during 980 -1120 cal. BP (Lu -8685). Thus, in the Middle - Late Holocene, after reaching of the maximum sea level, there were at least two pyroclastic outbursts.

The deposits of Vetrovoy Isthmus were studied on the sections of the sea and ocean sides coastal ledge and the data of manual drilling in the central part of the isthmus. All obtained geological data are correlated with the average level of the Okhotsk Sea. Georadar survey allowed to complement considerably the results of manual drilling of Vetrovoy isthmus and geological sections (Figure 3). A device Geotech EYE-2 (the antenna is 150 MHz) with a maximum penetration depth up to 15m and a resolution at a depth of about 35 cm was used for temporary geological sections receiving. To display correctly the relief along the profiles, a tachometric survey with inaccuracies compensation in determining the distance by the wheel and control marks every 50 meters was carried out. The foot of the sand-pebble sediments, which was defined by us as marine, lies at the depth of 0-+1 m relatively to the average level (Figure 4).

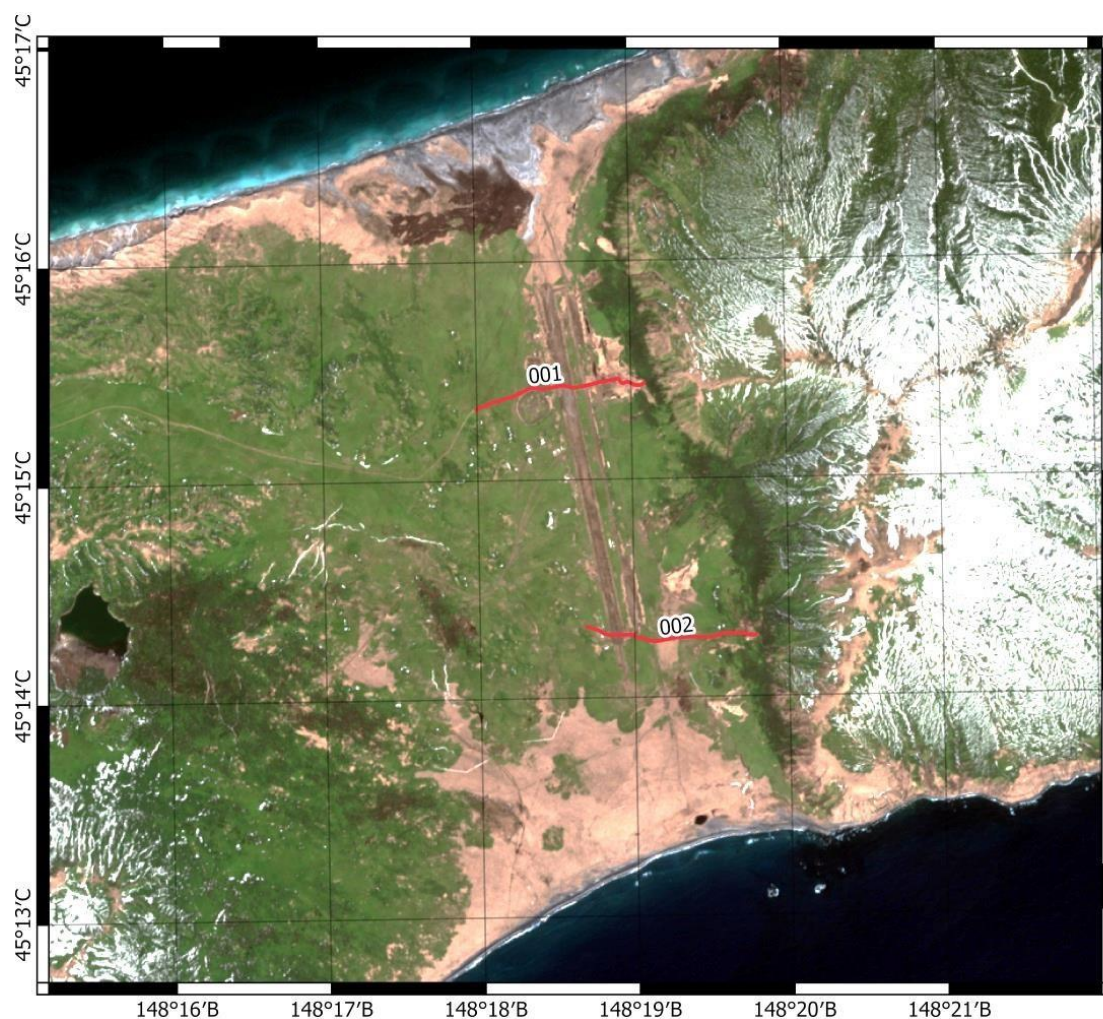


Figure 3. The location of georadar sections (Copernicus Sentinel data 2018).

The upper half-meter pack is represented as gray and sandy loam presumably of lagoon origin. Sea sediments are covered with about a meter layer of cover and sandy loams, that are replaced by sand and gravel-pebble formations closer to the ocean shore, a thin peat lay formed by 1450 -1710 cal.BP (Lu - 9222) is found at their basement. In the ledge of the ocean shore at marks + 2.2., that is about two meters higher than the base of the sand-pebble georadar facies, 15 cm peat bog of the same age 1300 -1440 cal.BP (Lu -9217) was opened in the base of the lagoon gray clays with a thickness about 3 meters. The peat layer lies directly on the strong Pliocene volcanits of the Kamui Suite(N2km) forming a bench in 500 meters to northeast at marks of average level of sea.

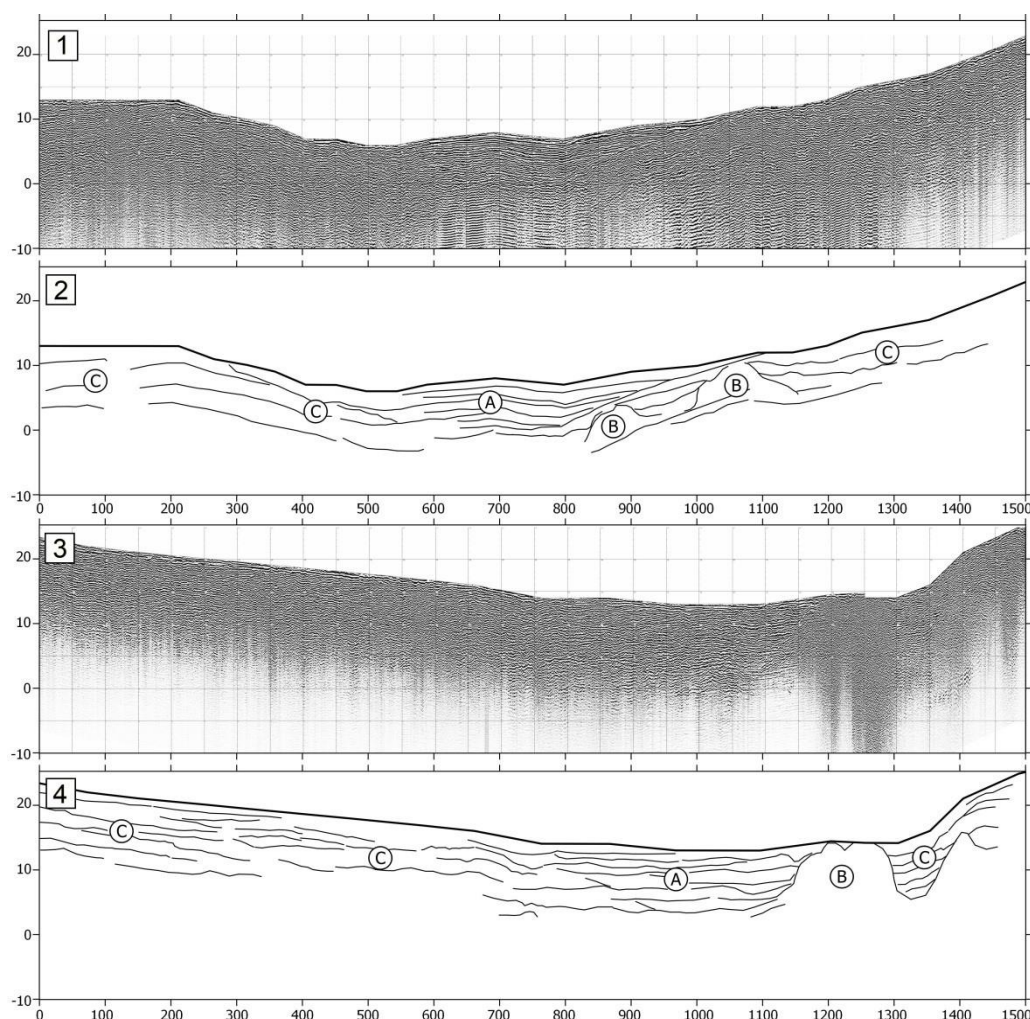


Figure 4. Georadar sections 1, 2; georadar facies – A – interstratification of sand-pebble deposits with different composition, shore-sea genesis, B – pumice massives, C – non-parting slope and shore-sea deposits with unknown composition.

A soil-tephra formation with thickness about 2 meters, lying on pumicious pyroclastic, was studied at 700 m to the southwest from this section. The soil horizon on contact with pumice has age of 1530-1790 cal.BP(Lu -9221) and mark +7.5 m relatively to average sea level.

Okhotsk sea coast of Vetrovoy Isthmus is a basement terrace generated in pumices and covered by aeolian deposits with thickness of 25-30 m (Figure 5). The surface slopes of the buried under the dunes pumice bench in the 300-400-meter strip of the coast are 1.4-1.60

In the middle part of the aeolian deposits there is an ash layer represented by white aleurolite. The formation of this layer occurred probably in the range from 250 l. n. (14C-dates 250 ± 45 AA-20942) till 800 l. n. (14C-dates 800 ± 80 l. n., AA-20941; 880 ± 40 l. n., GIN-7344) [16,17]. The sawn fragment of the tree trunk on the surface of the pumices in the coastal section at altitude of 2.7 meters testified about the young age of the dune. The inclination angle of the pumice surface covered with aeolian deposits on contact with a high coastal ledge is 4-5°. In 1100 meters to the south-west on the surface of the terrace-like ledge with a width of about 20 meters at an interval of 18-20 meters, aeolian deposits were also found. The inclination angle of pumicious surface of suggested marine terrace under aeolian sediments here is about the same value and at total 5-6°. It is interesting that the elevation marks of the profile bend of the terrace basement and the surface of the lagoon sediments, found in the area of Vetrovoy Isthmus, are coincide and at total 6.5 and 7.0 meters correspondingly.

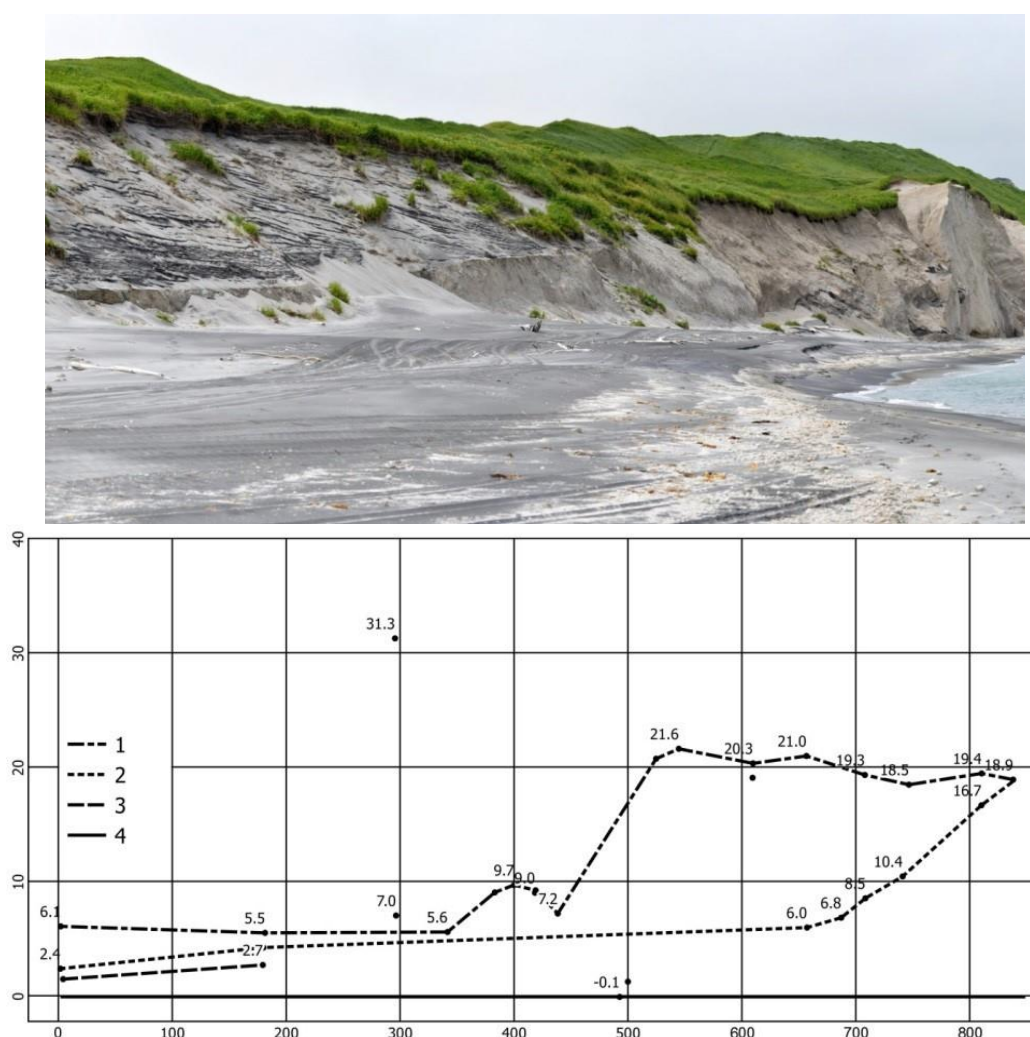


Figure 5. The structure of the coastal cliff on the south-western boundary of the Okhotsk Sea coast of Vetrovoy Isthmus. 1 – surface of aeolian sediments, 2 – surface of pumice bench, 3 – position of the back edge of the beach, 4 – average sea level.

4. Discussion and conclusions

The peculiarities of the Late Pleistocene-Holocene explosive volcanism manifestation aren't the subject of this study. However, obtained data indicate at least two large outbursts in the middle Late Holocene of pyroclastic material in the Vetrovoy Isthmus area. It is obvious that the products of explosive volcanism of this age contributed to the strait overlapping, and volcanic-tectonic deformations associated with eruptions near the central part of the isthmus, significantly complicated morphotectonic plan of the territory.

It is quite possible that the height increasing of the terrace surface of the middle Holocene age in the area of Vetrovoy isthmus by 2-3 meters relatively to the southern part of the island was connected with these events.

However, the morphometric parameters of the basement terrace indicate that during the last phase of coast-marine accumulation, the territory elevation rate could reach 4mm/year. This is few higher than 3.5 m/year in total for the last 6000 thousand years (according to data of R. F. Bulgakov).

Currently, there aren't data about the age of marine georadar facies established as a result of our researches on Vetrovoy isthmus. However, their geospatial position, the established time of deposits formation of estuarine-lagoon origin within the strait boundaries and dated coastal-marine sediments,

fixing the volcanic-tectonic events of the middle Holocene allow to suggest that in the Atlantic at the transgression peak, a strait existed on the site of Vetrovoy Isthmus. Given into account the speed of territory rising, its depth was 10-15 m. In the sub-Atlantic time, against the background of fairly rapid rising of the territory on the site of the mouth of the ocean part of the strait, there was only a lagoon pool.

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