

Reconstruction of Quaternary History of Southern Kuril Islands

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ABSTRACT

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Many researchers refer to uplifted marine terraces on the Kuril Islands (North Western Pacific), but there is no single opinion of their number, ages and altitudes. This study, which investigates this problem through field studies on the Kunishir, Iturup and Urup Islands of the Kuril Arc, found that the age of the low level terraces (2-10 m) lies in a time range from present to 5,000 BP. The peak of the Holocene transgression occurred near 4,000 BP and sea-level did not exceed the present level. Higher terrace levels range from 10 to 60 m above present levels. They were formed just before the last Glaciate (17,000 BP). Their radiocarbon ^{14}C age is about 27,000 BP. For planation surfaces at higher levels, there is no evidence to support marine origin except for the central part of the Urup. In the Southern Great Kuril Islands, evidence of marine sedimentation ended by the Pliocene-Early Pleistocene. In the southern Kunashir, there was no evidence of marine sedimentation after the Early-Middle Pleistocene. Local peripheral submergence occurred in the period 40 to 27 ka, when marine terraces obviously formed on Iturup and possibly on Urup. There are no traces of the Last Interglacial (125 ka) transgressions in the South Kuril Islands.

ADDITIONAL INDEX WORDS: *Kuril Islands, marine terraces, Pleistocene, sea-level, tectonic displacement, radiocarbon (^{14}C) dating, thermoluminescence dating.*

INTRODUCTION

It is apparent that the Quaternary history of the Kuril Islands is closely related to sea-level change and the crust displacement mode. Uplifted marine terraces described by many authors make reference to these events. The absence of a common opinion about ages, heights and the number of terraces makes the enigmatic history of not only the islands but the entire Kuril Arc system uncertain. Defining location, age, and altitudes of marine terraces was a major objective of these studies. The nature of islands (abundant volume of Quaternary volcanoclastics and scarceness of Quaternary sediments) requires consideration. The second objective of this paper is to describe the Quaternary development of the Kuril Islands.

STUDY AREA

The Kuril Islands chain is situated (Figure 1) between Hokkaido Island and the Kamchatka Peninsula. The Kuril Islands are the highest points of the submerged Great Kuril Arc Ridge. The largest of these islands is Iturup with a length of 190 km and a width of from 3 to 50 km. Kunashir and Urup are about 100 km in length. Most of the Kuril Islands are covered by Quaternary volcanic deposits, domes, and

cones and most of these Quaternary volcanoes are active. The base of the Quaternary volcanoes was formed by Neogene marine sediments interlayered by tuff and lava-flow depositions. The Neogene base and overlapped Quaternary volcanic deposits are intensively folded and intruded by magmatic bodies.

It is significant that the present day climate of the Kuril Islands is very severe: 60-90 day/yr strong storms (wind blows 15 m/sec and more) occur with heavy rain and snow fall; fog covers the Islands more than 180 day/yr; 2-8 strong typhoons with winds of about 50 m/sec reach the Islands every year; offshore ice remains about 77 day/yr; and in addition, the tide waves range from 1.2-1.7 m and the wind flood has an average range of 1.5-2.0 m (max 6 m) force on the island's beaches.

The tectonic setting of the southern islands is described by KIMURA (1986) as "a typical tectonic mode in oblique subduction zones." STRELTSOV (1991) criticized the oblique subduction tectonic mode thesis for the Southern Kuril Arc. By tracing the present altitude (0-200 m above present sea level) of the Last Interglacial (125 ka) shoreline on Hokkaido, OKUMURA (1988) demonstrated, "the eastward tilt of central Hokkaido and the western end of the Kuril fore-arc sliver has a gradient tilt as gentle as around 0.3/1000." Nevertheless, the Kuril Island is designated as a force 9 seismicity zone.

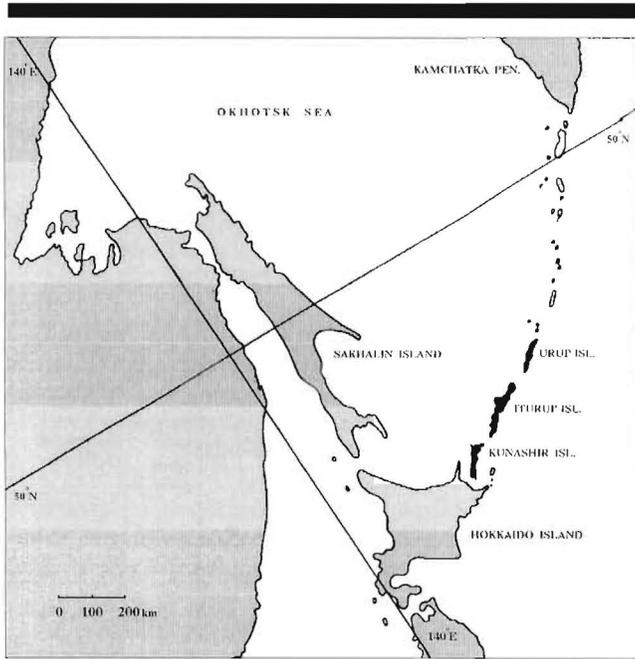


Figure 1. Location of the study area.

PREVIOUS STUDIES OF THE KURIL'S UPLIFTED MARINE TERRACES

The question of number, ages and altitudes of uplifted marine terraces on the Kuril Islands has been discussed for the last fifty years. KULAKOV (1973) reviewed previous works and suggested the terraces' level sequence as follows: low terrace level at 3–5 to 20–25 m, terraces at altitudes 30–40 m, 50–60 m, 80–120 m, 200–250 m (sometimes to 300 m). He emphasized that this sequence cannot serve as one standard for all the islands of the Kuril Arc. GRABKOV (1974) reviewed previous studies and conducted his own field research. He suggested the terrace sequence as: 2–3 m, 5–7 m, 15–20 m, 30–40 m, 60–80 m, 120–150 m, 200–250 m. After comparing the order of the Kuril terraces sequence with the order of the Alaska terraces sequence, he suggested the ages of the Kuril terraces as: Upper Holocene, Early Holocene, 25–30 ka, 78–100 ka, 170–175 ka, 100–400 ka, 600–1,000 ka consequently in ascending order. BRAITSEVA and MELEKESTSEV (1974) used radiocarbon datum of marine shells with an age of about 7,000 BP on Iturup Island (re-testing in this study gave an age of $5,350 \pm 150$ BP; GIN, 7094); he used radiocarbon data of peat with fossilized trees with an age of about 40 ka on the uplifted planation surface in the Kunashir. After assuming these data as the ages of marine terraces, he estimated the rate of crustal movements, extrapolated for the Late Pleistocene entirely and calculated possible terrace altitudes at different ages. Comparison of these ages with periods of climatic optimums during the Middle–Late Pleistocene suggested the ages of the Kuril terrace sequence. Those estimates are: 2–2.5 m—2–2.5 ka, 4–5 m—4–4.5 ka, 13–15 m—6–6.5 ka, 16–18 m—7–7.5 ka, 35–40 m—25 ka, 60–70 m—35

ka, 80–85 m—45 ka, 75–80 m—140–160 ka, 105 m (·) 190–210 ka, 120–130 m—230–250 ka, 350–370 m—375 ka.

KAPLIN (1973) conducted field studies on the Kuril Islands and concluded that marine terraces on Kunashir had altitudes of 2–5 m, 20–30 m, and 45–60 m. The altitudes for Iturup were 2–5 m, 20–30 m, 45–60 m, 90–100 m; and on Urup, they were 2–5 m, 20–30 m, 45–60 m, and 90–100 m—the same heights of marine terraces suggested by KANAEV (1960). KANAEV (1960) noted that there is not one correlative terrace level across all the Kuril Islands. He states that marine terraces of only 20–30 m developed on all of the islands. KAPLIN (1973) emphasized that at present on the Kuril Islands terrace-like surfaces cannot be evaluated without a chronological and stratigraphic identification, because there is no fossil faunistic data and radiometric data. Correlation of terraces becomes impossible because of intensive crustal movements along the islands. Previous researchers did not show the localization of strands which they considered to be marine terraces.

METHODS

Kunashir, Iturup and Urup Islands were visited by the author and field work completed over several years beginning in 1987. Geomorphologic surveys were carried out and samples collected for radiocarbon dating, thermoluminescence (TL) dating, and palynologic and diatomic analyses. Special attention was paid to beach and marine deposits on the uplifted strands. The origin of sediments was tested by diatomic analyses.

As calcareous rocks are absent on the Kuril Island, Quaternary dating methods based on the use of calcareous material are limited. Special attention was paid to the reliability of radiocarbon data. EVIN (1990) investigated the problem of validity of the radiocarbon dates beyond 35 ka and separated the dating materials into three classes: (1) *unreliable* (shells and calcareous secretions, brown layers in loess or sandy continental sediments); (2) *questionable* (charred bones, charcoal enriched by roots); and (3) *reliable* (unburnt bones, wood). The main reason for the unreliability of this method is contamination of the samples by ^{14}C from the atmosphere. In samples which were used for radiocarbon dating (the base peat, palae-soils interlayered with volcanic ash, tree cores in pumice), contamination occurred in two ways; organic material coming from the upper layer of surface soil and roots and rootlets that had penetrated into the sampled layers. During the sampling, we excluded such material from the analyses. This was not difficult because the Kuril Island's soils are organically pure and in thick pyroclastic layers, absent of vegetation and roots. Radiocarbon data were developed in the Geological Institute of the Russian Science Academy by L. SULERDJITSKIY and dubbed into the database of the Laboratory of the Pleistocene of Moscow State University by O. PARUNIN.

Ages of acid-pumice were determined by the "red light" thermoluminescence method. The method is described by (BULGAKOV, 1994). The low limit of Th, U, K (average content U—0.073 \pm 0.022%, Th—0.16 \pm 0.022%, K—0.98 \pm 0.3%) increases the TL-dating range about 1 mln/yr. Diatomic

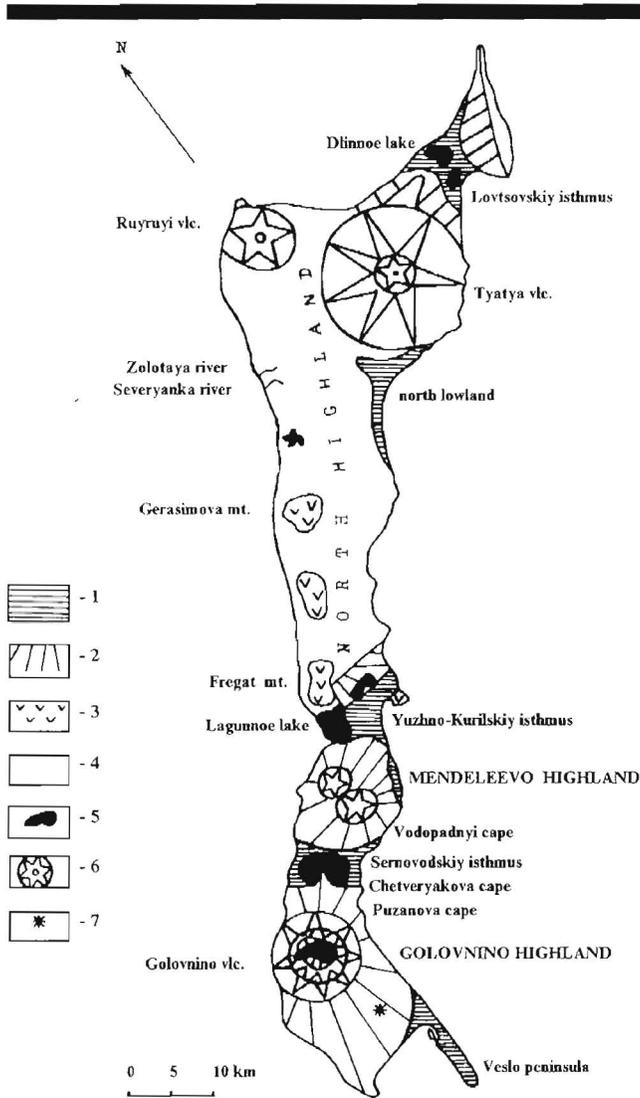


Figure 2. Geomorphologic map of the Kunashir island. (1) Lowlands and isthmuses, (2) highland planation surface, lines represent main dipping direction, (3) planation surfaces covered by lava flows, (4) base Neogene rock surfaces without planation, (5) lakes, (6) volcanic cones, and (7) location of the columnar section shown in Figure 3.

and palynology analyses were made in the Special Complex District of the Sakhalin Geologic Survey by V. BOLDYREVA and T. KOCHERGINA, respectively. Air reconnaissance surveys were used for geomorphologic mapping in addition to on-the-ground analysis and stereo-photogrametric studies.

UPLIFTED TRACES OF MARINE TRANSGRESSIONS AND THEIR RELATION WITH QUATERNARY DEPOSITIONS

The largest planation surface is located in the southern part of Kunashir (Figure 2). It is mainly composed of pumice and acid tuffaceous sand. The height of the surface gently increases up to the Golovnino Caldera from 5 m to 200 m

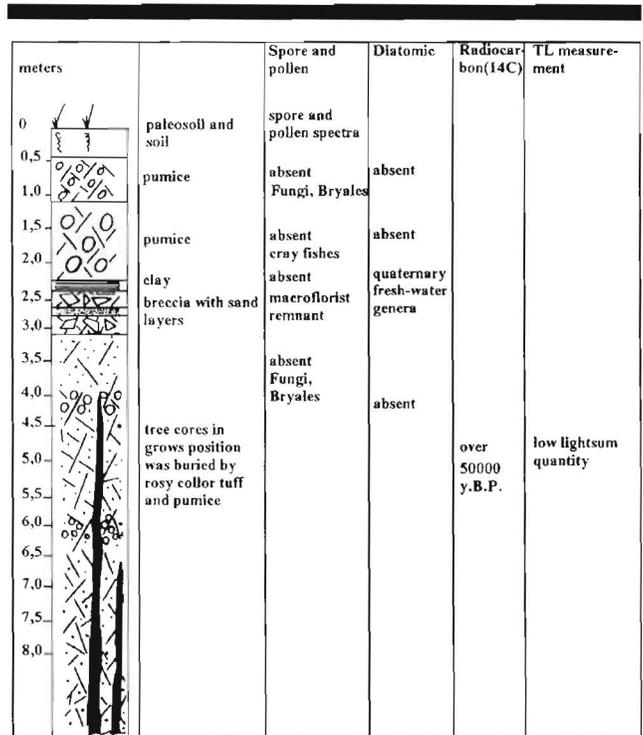


Figure 3. Columnar sections of exposure on the Golovnino highland (Kunashir island). The location of exposure is shown by asterisk in Figure 2.

above sea-level. These surfaces are dissected by river valleys at radial directions from Golovnino Caldera. Surficial sediments consist of thin interlayers of clay, pumice, sand and occasionally pebbles (Figure 3).

Diatomic analyses have shown fresh-water genera in samples from covered sediments. Base rocks forming the highlands are divided into lower and upper units. The diatom genera from the lower units indicate marine sedimentation conditions. The *Rhizoslenia Curvirostris* Jouse diatom species index provides an age for the lower unit in a range 130–700 ka. The age of the quartz extracted from this deposition and determined by the TL method is 700 ka with an uncertainty of 30%. The diatom genera and TL datum substantiate a Middle Pleistocene age for these depositions.

The upper unit is mainly pyroclastics flow, overlapped by lacustrine and freshwater sediments. Samples used for the radiocarbon analysis of tree cores in growth positions were taken from a depth of more than 8 m from the surface. Figure 3 gives an age of $50,200 \pm 890$ BP (GIN 6512). This datum is over the limit for the radiocarbon method; but if this datum is taken into account as an upper limit of age, one can conclude that this location emerged over the sea-level in the last 50 ka, and the Kunashir southern planation surface could not have had a marine planation genesis. TL-measurement of quartz from the pyroclastic flow that buried these tree cores gave the small quantity of a light-sum, proving that radiocarbon data does not provide an accurate measurement.

Therefore, it is clear that the southern part of Kunashir emerged not later than the Middle Pleistocene. There is no

evidence of later marine submergence in this area. The Last Interglacial transgressions (125 ka) did not leave traces of marine or beach depositions. OKUMURA (1988) traced the Last Interglacial surface on Hokkaido. This surface is submerged below present sea level (PSL) in the Konzen Lowland which is adjacent to Kunashir. KAPLIN (1973) reported the presence of peat interlayers at a 2 m depth beneath the bottom of the South-Kuril Strait between Kunashir and the Shikotan Islands. These interlayers were not dated but KAPLIN suggested the Late-Late Pleistocene (Middle Würmian) age for them.

There are abrasion type beaches at the periphery of the Southern Kunashir, except the Veslo Peninsula and its small adjacent area (Figure 2). Special investigations of the abrasion rate were not made but the absence of wide sandy beaches and recent landslides at the cliff confirmed the intensity rate. PAVLIDIS (1968) demonstrated that the Veslo Peninsula is an accumulative beach body which formed at the Post-Glacial or maybe during Recent time. All of these results confirm that the Southern Kunashir area remained emerged above high sea-level during the Last Interglacial (125 ka) period.

The next large planation surface is located at the western side of the Mendeleevo Volcano (Figure 2). This surface is composed of acid ashes and andesite tuffs. Diatom analyses of samples from this surface showed mostly freshwater or the absence of diatom species. POLUNIN (1969) investigated the planation surface from the eastern seaward side of the Mendeleevo Volcano. Radiocarbon data from the lignite interlayer, under thick (100 m) tuff cover at the height of about 10 m above PSL, gave an age of $40,200 \pm 50$ BP. Diatom analyses of the samples surrounding the previously dated lignite interlayer showed boreal freshwater genera with brackish and salt water species. Pollen analyses show the temperature was previously colder. The similar cold fresh, brackish conditions of diatom genera was found at the Vodopadnyi Cape during this study. Furthermore, marine depositions were found on the northern side of that highland at a height of about 10 m above PS (Figure 4). Deposits are represented by silt-clay sediments enriched by fossil fragments from seaweed. Diatom analyses of samples from these sediments (made by V. PUSHCARO) gave boreal marine genera.

The eastern and north-eastern periphery of Mendeleevo Highland had a connection to the open sea. The time of the lowest positions of this area was the Late-Late Pleistocene (upper limit 40 ka, maybe older with contamination as recent as ^{14}C , but cold climatic conditions show that it did not have the climatic optimums of the 125 ka or earlier).

Base rocks underlayered the Late-Late Pleistocene sediments represented by acid tuffs belonged to the Neogene as shown by ZJITKOVA *et al.* (1972). These Neogene rocks are exposed on cliffs at the western seaward side of the Mendeleevo Highland. These rocks were not retested for age in this study. The age of the pumice deposition at the northern part of the highland, near Lagunnoe Lake (Figure 2) was 500 ka (30% uncertainty) by the TL method. There is no evidence of marine sedimentation conditions as exist at the low-unit of Golovnino Highland.

The largest northern highland of Kunashir consists of Neogene rocks (ZJITKOVA *et al.*, 1972). The median height of this

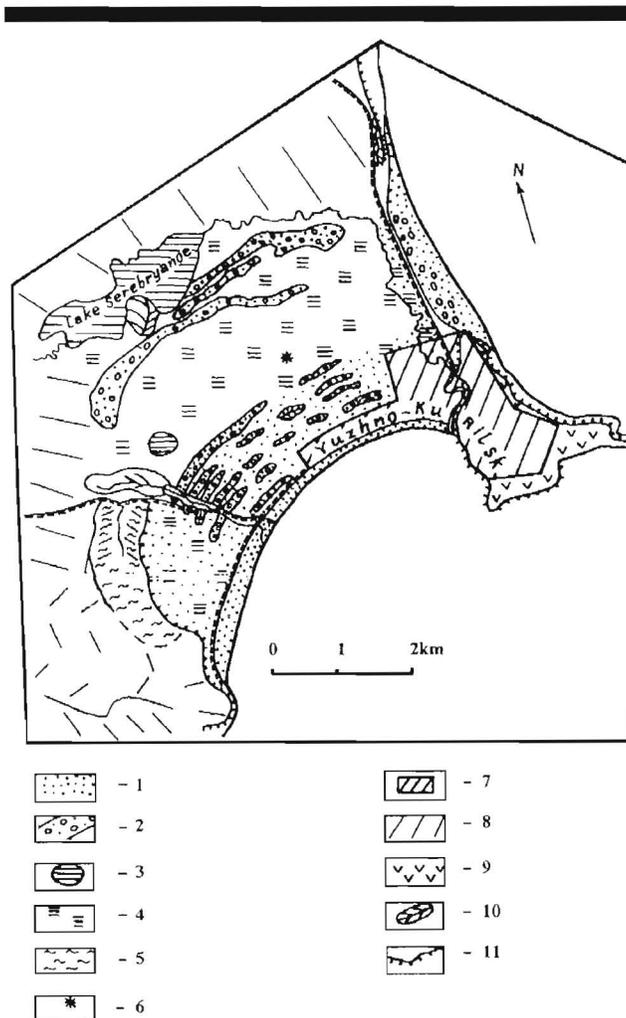


Figure 4. Geomorphologic map of the eastern side of the Yuzhno-Kurilskiy isthmus (Kunashir island). (1) Sand beaches and dunes, (2) beach ridges, (3) lakes, (4) peat swamp, (5) marine depositions, (6) location of the radiocarbon dating, (7) settlement, (8) planation surfaces, (9) lava flows, (10) residual surfaces, (11) beach cliffs.

highland is about 600 m. The western side of the northern highland is higher than the eastern side. There are no distinct subhorizontal planation surfaces, except the lava flow covering surfaces of the Fregat, Treugolnic, Morozova, Gerasimova Mountains at the western side of the highland (Figure 2). A large lowland area occupies the eastern side of the north highland (Figure 2). The seaward surface of that lowland is composed of sand with a dune system. Acid tuff deposits appear on the inner side; this deposition was not investigated to determine age and origin for this study. Pebbles, sand, clay and silt layers were found over the last lava-flow from the Tyatya volcano (Figure 2). The thickness of these sediment layers is about 1 m and the height is 40 m above PSL. Sediment layers underlie the tuff deposits with about a 10 m thickness.

The northern highland is intensively folded and intruded

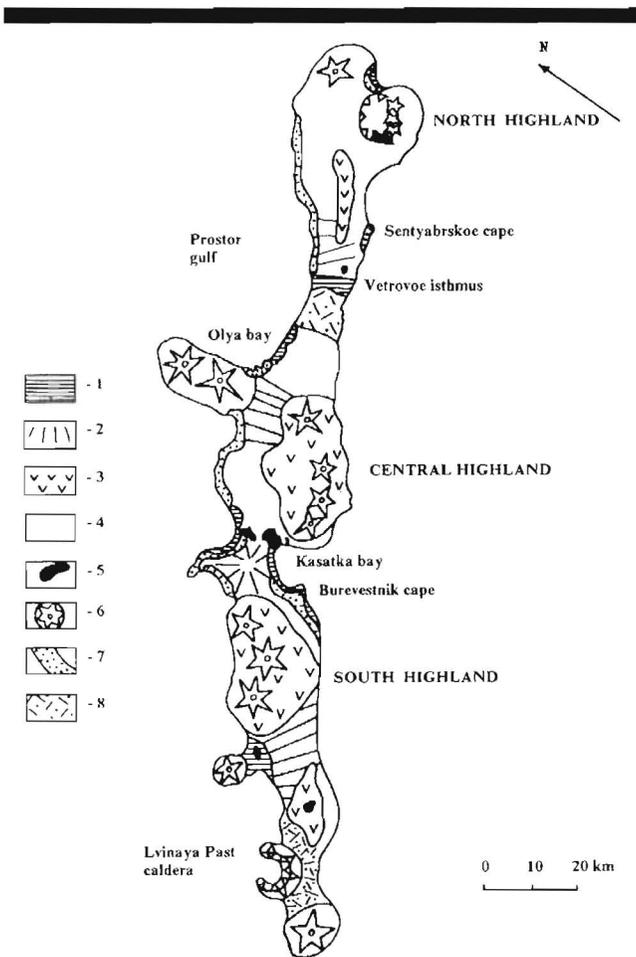


Figure 5. Geomorphologic map of the Iturup island. (1) Lowlands, isthmuses and Holocene terraces, (2) highland planation surfaces, lines represent dipping direction, (3) lava flows and volcanoes, (4) base Neogene rock surfaces without planation, (5) lakes, (6) volcanic cones, (7) Upper Quaternary marine terraces at altitudes 10–60 m above present sea level, (8) thick pumice's deposits.

by magmatic bodies. Most of the folded zones are eroded by rivers with wide and deep valleys. The valley of the Zolotaja River on the western side of the highland has been excavated to the base rock. The radiocarbon age of the silt layer, enriched by organic fossils in the alluvial valley sequence was $4,050 \pm 40$ BP (GIN 6513). The dated layer was situated below the PSL. A similar sediment sequence was found in the adjacent Severianka River Valley using wide diameter drill boring equipment. Quaternary marine transgression traces have never been found at the Northern Highland of Kunashir.

The Holocene marine transgression was investigated on the lowland isthmuses. There are three isthmuses on Kunashir Island, Sernovodskiy, Yuzhno-Kurilskiy and Lovsovskiy (Figure 2). The largest of them is the Yuzhno-Kurilskiy Isthmus. At the western side of this isthmus, there are distinct beach ridges along the shoreline, following each other on the inner side (Figure 4). Beach ridges are composed of sands and peb-

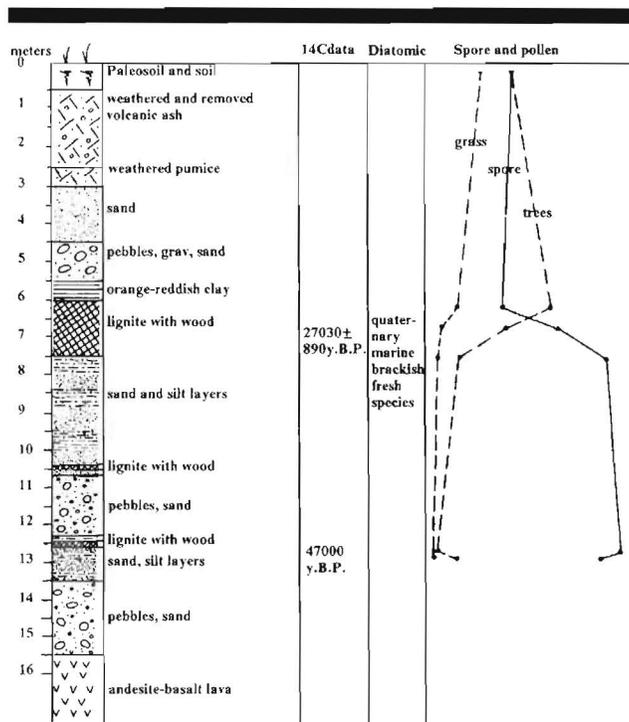


Figure 6. Columnar sections of exposure on the Olya bay. The location of exposure is shown by asterisk in Figure 5.

bles. The inner area, located beside the beach ridges, is covered by swamp and has peat of a maximum thickness of about 0.7–1.0 m. The lower part of the peat was dated by the radiocarbon method and given an age of $1,330 \pm 80$ BP (GIN 6518). The peat is underlain by sand. Apparently, during the Late-Late Pleistocene, the eastern side of the Yuzhno-Kurilskiy Isthmus was below sea level. Marine sediments were preserved after this transgression in the south-eastern part of the isthmus (eastern–north-eastern Mendeleevo Volcano). Later, the central part of the eastern side of the isthmus dropped tectonically. The Holocene transgression eroded out Late Pleistocene marine sediments and filled in the Holocene sand deposits. There is no evidence that the western side of the Yuzhno-Kurilskiy Isthmus has been submerged since 500,000 BP. During the Holocene transgression, Lagunnoe Lake and other small lakes at the western side of the isthmus were separated by beach ridges.

Sernovodskiy lowland is a graben which formed during the Late Pleistocene. This is confirmed by TL dating of the pumice composing the walls of the graben (50 ka with an uncertainty of 30%). Diatom analyses of a sandy layer beneath the graben wall's pumice (at the Vodopadnyi Cape) indicated a freshwater Quaternary species. At the peak of the Holocene transgressions, the inner part of the lowland was separated by beach ridges both on the western and the eastern side; Sernovodskiy Lake was formed.

The Lovsovskiy lowland was also formed by tectonic submergence. It is very likely that during the Pleistocene the lowland was a freshwater lake. Fragments of correlative sed-

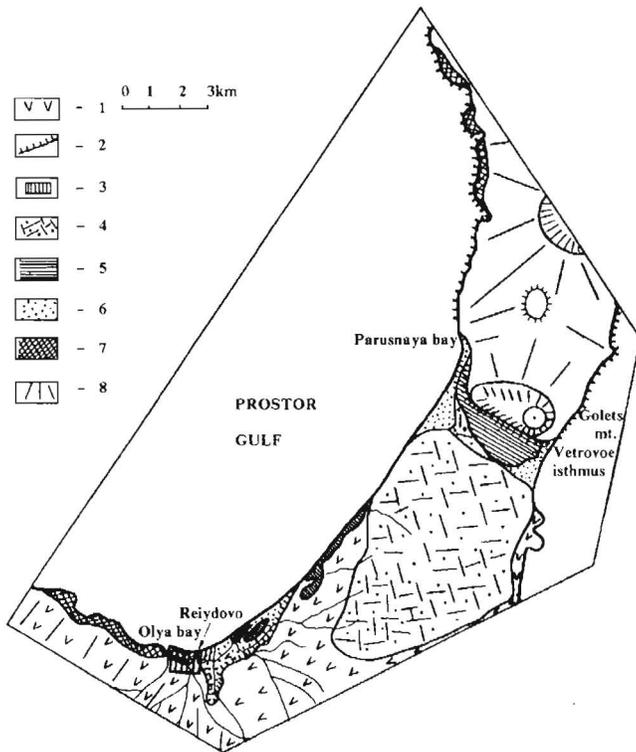


Figure 7. Geomorphologic map of the Vetrovoe isthmus and adjacent area (Iturup island). (1) Lava flows, (2) beach cliffs, (3) settlement, (4) thick pumice deposits, (5) Holocene uplifted terraces, (6) sandy beaches and dunes, (7) Upper Quaternary uplifted marine terrace, (8) surfaces of lava flows or planation surfaces, lines represent main dipping directions.

iments remain in the central part of the lowland near Dlinnoe Lake (Figure 2). Analyses of diatoms in these sediments indicates a freshwater Quaternary species. TL analysis of the base of these sediments provided a limit to the method ("saturation"). The age of the base, taking into account its low level radiation, exceeded 1 m/yr; the diatomic age of the base is Late Miocene.

At the next Iturup Island, the well preserved high marine terrace level is present above the beach cliffs over most of the island at 10–60 m (Figure 5). This terrace has a gently dipping surface of about 100–200 m in width and a distinct ancient cliff in the inner section. Frequently, a beach-like, pebble cover-layer can be found under Recent soil. Most of the terrace surface cuts into the base rocks. The accumulative body of this terrace was found at Olya Bay in Reidovo Town. It is represented by sedimentary layers of sand, pebbles and lignite (Figure 6). The radiocarbon age of the upper lignite interlayers is $27,030 \pm 700$ BP (GEO 44), and the radiocarbon age of the lower interlayer is $47,000 \pm 2,000$ BP. Diatomic analyses of lignite sediments indicated brackish, salt and freshwater species. There was transgressive-type sedimentation which confirmed the high sea-level position at this time. The Late-Late Quaternary age of these terraces was demonstrated with the polynological method by ALEXANDROVA (1971). The radiocarbon analyses of the peat swamp

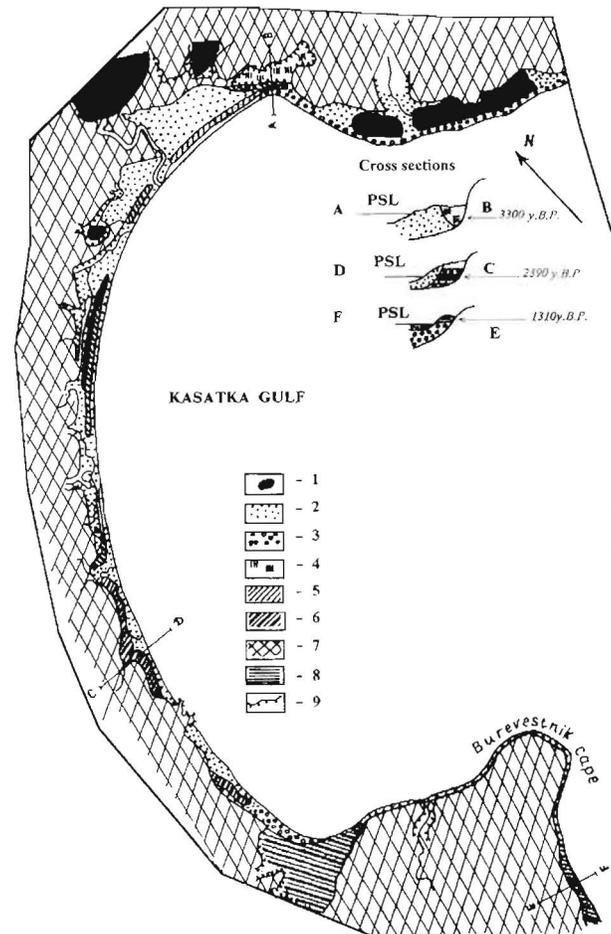


Figure 8. Geomorphologic map of the Kasatka Gulf area (Iturup island). (1) Lakes, (2) sandy beaches, (3) pebble beach, (4) peat, (5) dunes, (6) Holocene terrace, (7) surface of Upper Quaternary terrace, (8) lignite, (9) beach cliffs.

on this terrace near the Sentyabrskoe Cape (Figure 5) gave an age of $6,970 \pm 90$ BP (GIN 6515). Taking into account that this datum was not obtained from the base of the peat layer, one can prove that the terrace was formed during a pre-Holocene time. This terrace exists in the central and northern Highlands of Iturup Island (Figure 5).

Thick pumice deposits (20–100 m) cover the southern part of the island around the volcanic Caldera Lvinaya Pass (Figure 5) and the central part of the island in the Vetrovoe Isthmus (Figure 7). The radiocarbon ages of tree cores buried by pumice in the Caldera Lvinaya Pass are: $10,370 \pm 640$ BP, $9,270 \pm 490$ BP, $8,750 \pm 230$ BP, $6,850 \pm 160$ BP, by GRABKOV (1991); and $6,850 \pm 160$ BP by MELEKESTSEV *et al.* (1990). The lignite interlayer under this pumice has a radiocarbon age of $26,175 \pm 350$ BP (GRABKOV, 1991). The age of the Vetrovoe Isthmus pumice is 20 ka with an uncertainty of 30%, arrived at by the TL method. The radiocarbon age of the organic remnants in silt under pumice is $38,500 \pm 500$ BP (GIN 7092). The radiocarbon age of the shells above the

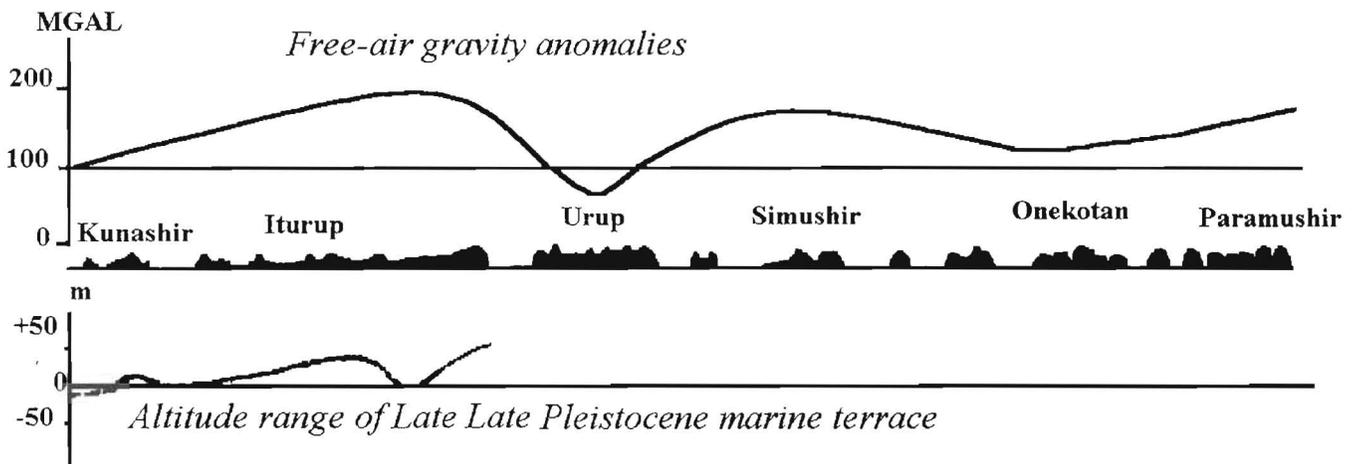


Figure 9. Profiles of free-air gravity anomalies and altitude positions of Late-Late Pleistocene marine terrace along Kunashir and Iturup Islands.

pumice is $5,350 \pm 343$ (GIN 6776). Iturup's high terrace level is submerged below PSL with pumice cover, both in the southern and central parts.

There are no confirmed traces of marine planation surfaces on the highest points of Iturup Island. The marine terraces encountered on Iturup are at a low altitude (2–6 m PSL). These terraces are connected by lowlands and large river mouths. They are usually covered by dunes. These marine terraces are most apparent in the Kasatka Gulf and begin south of Cape Burevestnic (Figure 8). In the northern part of the bay, these terraces are not uplifted; they continue as beach ridges. The position of the peat and sediment with organic remnants dated by the radiocarbon method are shown in the cross sections (Figure 8).

It is clear that the uplift rate of the southern part of the Kasatka Gulf beach is not indicated, because there is no shoreline erosion in the bay. The age of these terraces (radiocarbon dating) is younger than 5,000 BP and older than 1,300 BP.

Holocene marine terraces exist on the beaches of Prostor Bay (Figure 7). The altitude of these terraces is about 6 m above PSL and the maximum width is 200 m. There are pebbles covering the surface. Vetrovoe pumice depositions (with a TL age of about 20 ka) are overlapped by sedimentary terraces with a cover that includes pumice. Radiocarbon dating of shells from the terrace cover confirmed an age of $5,350 \pm 50$ BP (GIN 7094). Recent uplifting and tectonic displacement on Vetrovoe Isthmus is verified by the oblique sediment layers on the Golets intrusive magmatic body.

Most of Urup's base rocks are composed of welded "green tuff" depositions of the Neogene age. Quaternary and active volcanic cones and deposits parched the base rocks. Morphological observations allowed the identification of the low level terraces; they are composed of alluvial and dune sediments connected with the large river mouths. The height of these terraces ranges from 2 to 6 meters above PSL. Their Recent age was established by the pattern of industrial goods, fishermen's nets and floats, and boxes found in and on the ter-

aces. A terrace, 20 m to 60 m high with a width of about 100 to 200 meters, is similar to the Iturup terraces; it has an occasional cover of sand and pebble sediment, but for the most part has no sediment at all. This terrace is distinct in the northern and southern parts, but not in the central part of the island. There is no radiometric determination of the age of this terrace and no proof of its marine origin exists; however, pebbles and thick sand deposits suggest that its origin is marine. (This study found pebble deposits (2 m) on the large planation, lava covered surface in the central part of Urup.)

DISCUSSION

Data presented in this paper does not agree with results reported by GRABKOV (1974) and BRAITSEVA and MELEKESTSER (1974). They suggested that uniform tectonic uplift occurred on the islands of the Great Kuril Arc during the Pleistocene. The absence of marine deposits younger than the Late Pliocene on large parts of the islands, the results of diatomic analysis, and the absence of marine terraces on the surface confirm the idea that terrestrial conditions dominated after the uplift. Emergence of such island patterns is initiated, not only by tectonic uplift but also by an accumulation of thick volcanic deposits during the Pleistocene.

This study found no evidence of marine transgression on Kunashir and Iturup Islands from the Early Middle to Late-Late Pleistocene although the author was eager to locate evidence of the Last Interglacial transgression (125 ka). Since there is no evidence of this transgression, *i.e.*, traces on the recent dry uplands, one can believe that the larger part of the islands were high and dry at that time, but had been submerged during the Late-Late Upper Pleistocene before the maximum impact of the last Glaciation and reemerged during the Last Glaciation and the Holocene.

Tectonic displacement occurred at different rates in different Island's tectonic blocks. Nevertheless, the vertical crust movement since the Late-Late Pleistocene had an up-



Figure 10. Photographs of locations discussed in the text: (a) Kunashir's north highland beaches. There are no uplifted marine terraces. (b) Alluvial deposits in the Zolotaya river valley (Kunashir). Radiocarbon age of silt enriched by organic material in the low part of the scarp is $4,050 \pm 40$ BP. (c) The Late-Late Pleistocene marine terrace (Iturup) just above the present cliff. There is no evidence of marine origin of the upper planation surface.

lifting trend from Southern Kunashir to Northern Iturup (Figure 9). This crustal movement trend coincided with a free-air gravity anomaly trend and a volcanic activity trend. Magmatic intrusions provoked uplift in the adjoining crustal blocks and caused disturbance of the isostatic balance. After finishing the magmatic process, uplifted blocks settled downward according to the rules of gravity. This process

repeated periodically. Ancient marine terraces eroded during the submergence period but new marine terraces were formed. This is a rough explanation for the absence of ancient, high uplifted marine terraces in the Southern Kuril Islands.

Observation of the Kunashir and Iturup lowlands indicated that the peak of the Holocene transgression occurred



Figure 10 cont. (d) Beach-like pebbles on the surface of the Upper Quaternary marine terrace. (e) The low marine terrace with an age of 1,300 BP and the Upper Quaternary marine terrace at the Burevestnik cape (Iturup). (f) The southern part of the Iturup without terrace-like surfaces.

about 4,000 BP. The absence of Holocene marine terraces at the most recent beaches of the islands lead the researchers for this study to conclude that Holocene transgression did not exceed PSL in the Kuril Island region. The numerical calculation of eustatic changes during the last 15,000 yr (CLARK *et al.*, 1978) indicated that the Holocene transgression did not exceed 1 m above PSL in the Kuril Islands Region of the North Pacific.

CONCLUSIONS

Emergence of the Southern Kuril Islands occurred during the Pliocene–Early Pleistocene period. Only the southern part of Kunashir remained submerged until the Middle Pleistocene and then emerged after 700 ka. High sea-level positions were also marked on the Rkukyu Islands (South Japan) between 500 ka and 850 ka by IKEDA *et al.* (1990) by use of

ESR dating of corals. The high sea-level position of the worldwide Last Interglacial (125 ka) did not leave traces on the surface of Kunashir and Iturup Islands. Well preserved marine terraces with altitudes of from 10 to 60 m and ages of 27–47 ka exist on Iturup Island. Traces of this transgression in the form of marine and beach sediments are found on Kunashir Island. There is no confirmation of a sea level higher than the present during the maximum of the Holocene transgression (6,000 BP) on the southern Kuril Islands.

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LITERATURE CITED

- ALEXSANDROVA, A., 1971. Some stratigraphical questions with Quaternary depositions of the Iturup Island. *Reports of the Sakhalin Branch of the Geographical Society of the USSR*, v. 2, pp. 74–82 (in Russian).
- BRAITSEVA, O. and MELEKESTSEV, I., 1974. *Volume, Sequences and Questions of the Study of the Earliest Period of Relief Developing: Kamchatka, Kurils and Commodore Islands*. Moscow: Izdatelstvo Nauka, pp. 83–99 (in Russian).
- BULGAKOV, R.F., 1994. Application of thermoluminescence dating on the Kuril Islands. *Modern Geology*, 20, 181–187.
- CLARK, J.A.; FARREL, W.E., and PELTIER, W.R., 1978. Global changes in postglacial sea-level, a numerical calculation. *Quaternary Research*, 9(3), 265–287.
- EVIN, J., 1990. Validity of the radiocarbon dates beyond 35,000 years BP. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 80(1), 71–78.
- GRABKOV, V., 1974. Marine terraces sequences as reference Pleistocene vertical crust movements of the North-Western Pacific: Geologic problems of the Sakhalin and Kuril Islands. *Vladivostok*, 31, 151–158 (in Russian).
- GRABKOV, V., 1991. *Personal Communication*.
- IKEDA, W.; KASUY, M., and IKEY, A.M., 1990. ESR ages of Middle Pleistocene corals from Ryukyu Islands. *Quaternary Research*, 36, 61–71.
- KANAEV, V., 1960. Geomorphological watching on the Kuril Islands. *Proceedings of the Oceanology Institute*, v. 32 (in Russian).
- KAPLIN, P., 1973. *Recent History of World Ocean Beaches*. Izdatelstvo Moskovskogo Universiteta, 265p. (in Russian).
- KIMURA, G., 1986. Oblique subduction and collision: Forearc tectonics of the Kuril Arc. *Geology*, 87(11), 404–407.
- KULAKOV, V., 1973. *Quaternary Shorelines of Okhotsk and Japan Sea*. Novosibirsk: Izdatelstvo Nauk, 188p. (in Russian).
- MELEKESTSEV, I.; BRAITSEVA, O.; PONOMAREVA, V., and SULERDJITSKIY, L., 1990. Age and forming dynamics of active volcanoes of the Kuril-Kamchatka region. *Izvestiya Akademii Nauk SSSR, seriya geologicheskaya*, no. 4 (in Russian).
- OKUMURA, K., 1988. Quaternary collision tectonics in Hokkaido, North Japan. *DELP Tokyo Symposium*, p. 94.
- PAVLIDIS, Y.A., 1968. *Some Peculiarities of the Formation of Recent Beach Deposits in the Volcanic Archipelago*. Moscow: Izdatelstvo Nauka, 111p.
- POLUNIN, G., 1969. About the absolute age of the high altitude terrace and Mendeleevo Volcano on the Kunashir Island. *Volcanologic Stations Bulletin*. Moscow: Izdatelstvo Nauka, no. 45, pp. 53–56 (in Russian).
- SHLUKOV, A., 1989. *Personal Communication*.
- STRELTSOV, M., 1991. *Shifting Tectonic and Mechanical Model of Islands Arcs*. Vladivostok: Tikhookeanskaya Geologiya (in Russian).
- ZAKHAROV, V.; VASILENKO, N.; POBEDONOSTSEV, S.; NAUMOV, N., and KUDELKINA, T., 1987. Recent crustal movements. In: KRASNYI, L. (ed.), *Geology-Geophisian Atlas of the Kuril-Kamchatka Island System*. Leningrad Kartfabrika VSEGEI, 27p.
- ZAITKOVA, L.; BEVZ, V.; ILJINA, A.; CRISHTOFOVICH, L.; NEVEROVA, T.; SAVITSKIY, V., and SAHEREMETJEVA, G., 1972. *Atlas of Neogene Shells of the Kuril Islands*. Moscow: Izdatelstvo Nauka, 66p. (in Russian).