^{14}C DATING OF LATE PLEISTOCENE–HOLOCENE EVENTS ON KUNASHIR ISLAND, KURIL ISLANDS

V. B. BAZAROVA, N. G. RAZJIGAEVA, T. A. GREBENNIKOVA, L. A. GANZEY, L. M. MOKHOVA, A. M. KOROTKY

Pacific Institute of Geography, Far East Branch of the Russian Academy of Sciences
Radio Street 7, Vladivostok 690041 Russia

and

L. D. SULERZHITSKY

Geological Institute, Russian Academy of Sciences, Pyzhevsky Per. 7, Moscow 109017 Russia

ABSTRACT. Kunashir Island is a very important site for paleoenvironmental reconstructions. Until recently, very little information on Quaternary deposits was available. We studied the environmental evolution of this oceanic island under the influence of geomorphological processes, volcanism and strong marine currents. This paper presents new data that allow a detailed reconstruction of the environmental development of Kunashir Island during the Late Pleistocene–Holocene, based on *ca.* 80 radiocarbon dates and diatom, pollen and sedimentological data. The vegetation development reflects climate changes and warm/cold current migrations.

INTRODUCTION

Kunashir is the largest southern island of the Kuril Island arc, stretching from Hokkaido Island to southern Kamchatka. Kunashir Island is *ca.* 123 km long and is from 7 to 35 km wide, covering an area of 1490 km^2. It stretches from 43°40′ to 44°30′N latitude and from 145°23′ to 146°30′E longitude and is divided by the Izmena Strait (15.5 km wide) from northeastern Hokkaido (Fig. 1). The island is surrounded by the Pacific Ocean to the east and the Sea of Okhotsk to the west. Kunashir has a monsoon-type climate. During the winter, intensive cold and dry air masses move in from Asia; during the summer, cool and moist air comes from the Pacific. The vegetation of Kunashir Island is characterized by two different botanical environments (Vorobiev 1963). The northern part of Kunashir Island is mainly occupied by fir forests. The southern part of the island is occupied by mid-temperate broadleaf and mixed-coniferous forests, as well as broadleaf forests. These forests include *Quercus crispula, Q. dentata, Acer pictum* and *A. ukurunduense,* associated with *Kalopanax septemlobum, Phellodendron sachaliense, Cerasus sachalinensis, C. maximoviczii, Ulmus laciniata* and *U. propinqua*. Conifers are represented by *Abies sachalinensis, Picea microsperma, P. Glehnii* and *Taxus cuspidata*. Thermophilous species such as *Magnolia obovata, Betula maximowiczii, Alnus japonica, Fraxinus manshurica, Syringa amurensis, Actinidia arguta, Botrocarium controversum* and some others are found only in this part of the Kuril Islands. The central part of the island forms the boundary between these two vegetation types.

METHODS

The key sections represent different terrestrial and marine facies (inshore, beach, lagoon, lacustrine, eolian and colluvial deposits, peat bogs, soils, buried soils and tephra layers). The sites were studied in 1993–1995. Paleoenvironmental reconstructions are based on radiocarbon dating, sedimentological and stratigraphical (diatoms and pollen) data. We dated >20 Kunashir Island sites. We used wood, peat, soil, charcoal and shells. The samples were first cleaned by manual removal of foreign material. Wood, charcoal and peat samples were further treated by acid/alkali/acid. The samples were decalcified using a hot 3% HCl solution; humics were extracted using a lN KOH solution and the extracted matter was acidified to pH 1.0 with dilute HCl to recover the humic fraction. The ^{14}C activity was measured by liquid scintillation counting. The first ^{14}C determinations for the Late Pleistocene Kunashir Island deposits were obtained by Polunin (1969) and Melekestsev *et al.* (1974); Bulgakov (1993) obtained the first determinations for the Holocene deposits.

Results and discussion

The ^{14}C dates for samples from various sites (Fig. 1) are shown in Table 1. In the following discussion we distinguish the Late Pleistocene and Holocene events.

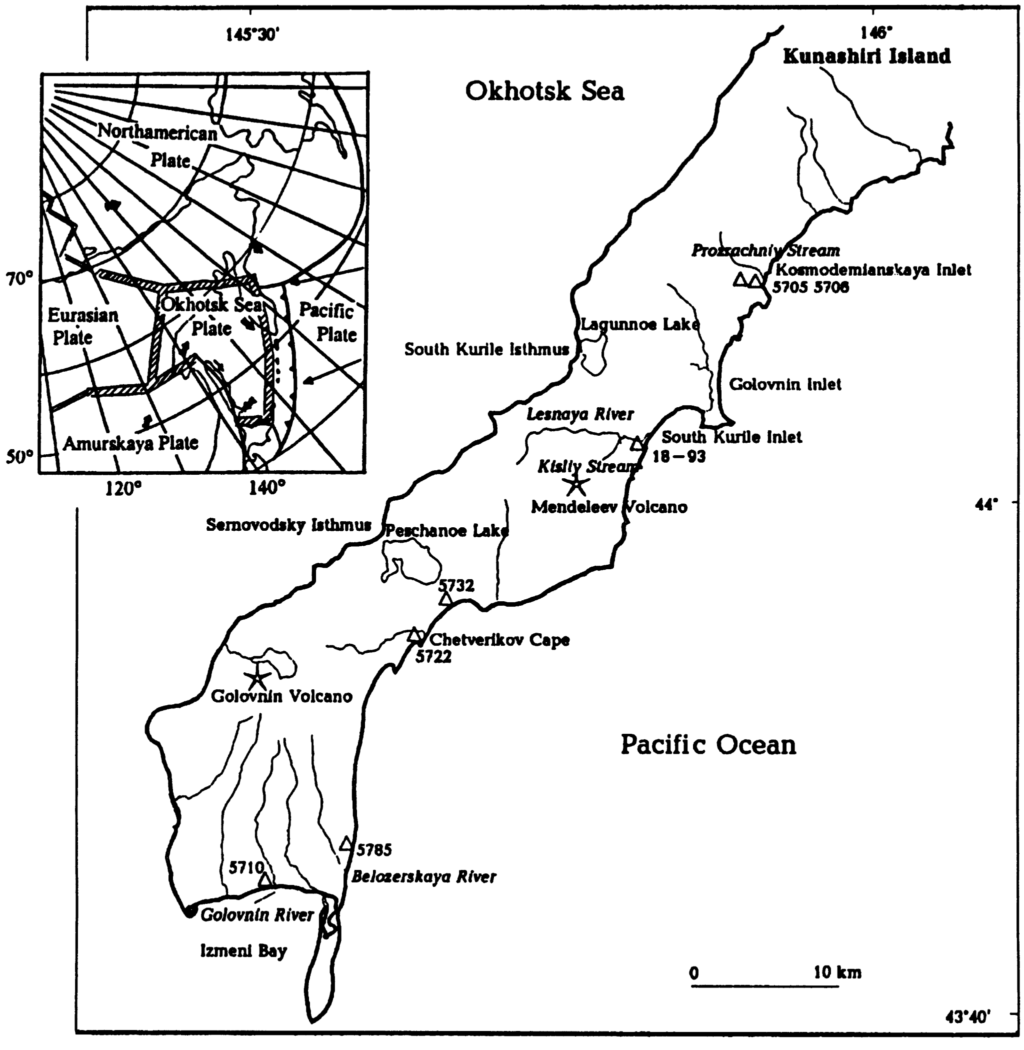

Fig. 1. Map of Kunashir Island (Kuril Islands, Russia)

TABLE 1. ^{14}C Age Data of Deposits of Kunashiri Island

Sample no.	Collection site	Position	Depth (m)	Material	^{14}C age (yr BP)	GIN- no.
I/5874	South of Puzanova Cape	80-m level		Wood	38,000 ± 1000	8345
IV/5874	South of Puzanova Cape			Wood	43,100 ± 1600	8346
III/5795	Belozyorskaya River mouth	8–10-m terrace	3.60–3.80	Peat	7670 ± 110	8625
II/5795	Belozyorskaya River mouth	8–10-m terrace	6.10–6.15	Peat	26,700 ± 900	8624
I/5795	Belozyorskaya River mouth	8–10-m terrace	6.50–6.85	Peat	42,300 ± 1500	8623
IV/5762	Belozyorskaya River mouth			Peat	39,500 ± 1000	7896
I/5762	Belozyorskaya River mouth			Wood	42,600 ± 1500	7877
I/5875	South of Puzanova Cape			Peat	32,300 ± 500	8434
I/3995	South of Puzanova Cape	40-m level	2.00–2.25	Peat	31,000 ± 1200	8622
I/5839	46 km from South Kurilsk	60–80-m level		Charcoal	30,500 ± 400	8347
I/5495	South of Puzanova Cape	Lacustrine deposits	0.25–0.40	Peaty silt	2570 ± 90	8628
II/5495	South of Puzanova Cape	Lacustrine deposits	0.55–0.65	Peaty silt	7180 ± 100	8629
I/5801	Lagunnoe Lake			Peat	6520 ± 110	8340
I/5815	South Kuril Inlet		2.00–2.15	Peat	5240 ± 50	8337
II/5815	South Kuril Inlet		2.40–2.45	Peat	5800 ± 70	8336
III/5815	South Kuril Inlet		2.80–3.00	Wood	6460 ± 100	8335
VI/5822	Serebryanka River				5020 ± 100	8433
VII/5822	Serebryanka River				5620 ± 100	8432
I/5936	Lesnaya River	6-m terrace		Peat	4260 ± 60	8435
II/5936	Lesnaya River			Peat	4970 ± 80	8436
III/5936	Lesnaya River			Peat	5750 ± 100	8437
IV/5936	Lesnaya River		2.10–2.20	Peat	5410 ± 40	8344
V/5936	Lesnaya River			Peat	6440 ± 100	8438
V/18-93	Lesnaya River mouth		0.20–0.40	Peaty silt	4010 ± 70	7880
IV/18-93	Lesnaya River mouth		0.40–0.56	Peaty silt	4100 ± 80	7871
III/18-93	Lesnaya River mouth		1.00–1.20	Peaty silt	5450 ± 150	7879
II/18-93	Lesnaya River mouth		1.40–1.60	Peaty silt	5890 ± 130	7878
I/18-93	Lesnaya River mouth		1.60–1.70	Peaty silt	6070 ± 170	7877
Ia/18-93	Lesnaya River mouth	5–6-m terrace	1.82–1.85	Peat	4310 ± 170	7876
I/5873	Golovnina Stream mouth			Peat	5760 ± 170	8439
I/5706	Kosmodemianskaya Inlet	5–6-m terrace	4.30–4.40	Peat	4570 ± 70	7889
II/5706	Kosmodemianskaya Inlet	5–6-m terrace	5.50–5.70	Peat	5750 ± 170	7891
III/6395	Fedyashina Cape	Peat bog	1.70–1.80	Wood	5360 ± 70	8630
I/5871	Fedyashin Cape, stream			Peat	4100 ± 50	8333
II/5871	Fedyashin Cape, stream	5-m terrace	3.00–3.10	Wood	5000 ± 70	8334
I/5813	Kosmodemianskaya Inlet	5–6 m terrace	2.00–2.20	Wood	4560 ± 50	8338
II/5813	Kosmodemianskaya Inlet	5–6 m terrace		Peat	4780 ± 100	8339
I/5858	Khebnikov Stream mouth	2-m marine terrace		Peat	2070 ± 30	8440
II/5858	Khebnikov Stream mouth	2-m marine terrace		Peat	2080 ± 80	8441
III/5858	Khebnikov Stream mouth	2-m marine terrace		Peat	2730 ± 60	8442
IV/5858	Khebnikov Stream mouth	2-m marine terrace		Peat	3790 ± 70	8443
V/5858	Khebnikov Stream mouth	2-m marine terrace		Peat	4600 ± 70	8343
I/5675	Golovnina Inlet	12-m dune	3.75–3.78	Charcoal	3840 ± 100	7885
III/5818	Golovnina Inlet	12-m dune		Charcoal	3650 ± 200	8342
7/3/93	Golovnina Inlet	3–4-m terrace	0.10–0.20	Shells	2950 ± 100	7875
I/5822	South Kuril Inlet	3–4-m marine terrace		Wood	Modern	8429
II/5822	South Kuril Inlet	3–4-m marine terrace	0.70–0.85	Peat	600 ± 60	8627
III/5822	South Kuril Inlet	3–4-m marine terrace		Wood	Modern	8341
IV/5822	South Kuril Inlet	3–4-m marine terrace		Peat	1960 ± 80	8430
V/5822	South Kuril Inlet	3–4-m marine terrace		Wood	2780 ± 60	8431
I/5708	Prozrachny Stream	4-m terrace	2.00–2.10	Shells	2620 ± 90	7892
I/5732	Sernovodsky Isthmus	4-m terrace	0.45–0.50	Peat	2220 ± 80	7895
I/5676	Golovnina Inlet	20-m dune	1.70–1.95	Soil	190 ± 40	7886
II/5676	Golovnina Inlet	20-m dune	3.80–3.95	Soil	2130 ± 50	7887
4/9-93	South Kuril Inlet	3–4-m terrace	0.30–0.40	Peat	510 ± 50	7873
6/9-93	South Kuril Inlet	3–4-m terrace	0.50–0.60	Peaty silt	1770 ± 40	7874
I/5778	Golovnina Inlet	20-m terrace	2.50–2.62	Soil	1460 ± 50	7898
I/5674	Golovnina Inlet	8-m dune	2.80–2.90	Peaty sand	1310 ± 80	7884
3/13-93	Pervukhina Inlet	12-m dune	3.00–3.40	Soil	290 ± 60	7870
5/13-93	Pervukhina Inlet	12-m dune	3.75–3.90	Soil	1260 ± 90	7871
7/13-93	Pervukhina Inlet	12-m dune	4.60–4.65	Soil	860 ± 140	7872
I/5891	Tyurina Stream mouth			Peat	850 ± 50	8428
I/5697	South Kuril Inlet	2-m terrace	0.40–0.50	Shells	820 ± 80	7903a
I/5816	South Kuril Inlet			Shells	280 ± 90	8444
I/3895	Near Otradnoe Village	8-m soil cover	0.35–0.38	Wood	Modern	8632
I/6295	South Okhotsk Sea coast	40-m marine terrace		Wood	Modern	8631
I/5687	Pervukhina Inlet	4-m terrace	2.00–2.10	Wood	Modern	7888

Late Pleistocene Events

^{14}C dates obtained from peat layers of the Belozerskie Beds of South Kunashir Island range up to *ca.* 42,000 BP. The Belozerskie Beds are widely spread around the Golovnin and Mendeleev Volcanoes, and they consist of different terrestrial deposits (up to 80 m thick) including pyroclastic flows, ash layers and volcanic shelf deposits, plus eolian, lacustrine, alluvial and peat units. The main source of these beds is the tephra reworked in different sedimentary environments. There are traces of cryogenic perturbation in these deposits, apparent from reworked material in the permafrost zone during the Last Glacial Maximum. The oldest ^{14}C dates were obtained from the peat layer at the base of the Belozerskie Beds. This peat is characterized by pollen with predominating tree and shrub pollen (up to 98.9%), with a high content of coniferous taxa. The amount of small-leaved taxa is small. The content of broadleaf tree pollen (*Quercus, Ulmus, Corylus, Juglans, Syringa*) is <2.9%. The amount of herb pollen is up to 15.8%. The pollen assemblages (*Picea* zone) show the development of dark coniferous taiga along with some small-leaved taxa. The climate was somewhat cooler than today. ^{14}C dates from these layers obtained from wood are 42,600 ± 1500 BP (GIN-7897), 42,300 ± 500 BP (GIN-8623), 39,200 ± 700 BP (GIN-7901) and 39,500 ± 1000 BP (GIN-7896) obtained from peat. They represent a Late Pleistocene warming period. The ^{14}C date 26,700 ± 300 BP (GIN-8624), obtained from peat of the same horizon, is probably rejuvenated. The diatoms assemblage and the presence of pollen of *Myrica* and *Cyperaceae* indicate the development of lacustrine environments and wetlands on the island and land bridge between Kunashir and the Hokkaido Islands. The elevation of lacustrine units in the section indicates that the sea level was lower than today. Similar ^{14}C dates—38,000 ± 1000 BP (GIN-8345) and 43,100 ± 1600 BP (GIN-8346)—were obtained from wood from the lower peat layer of the Belozerskie Beds, covering the southern Pusanov Cape. The pollen assemblage of this peat unit corresponds to *Picea*. These ^{14}C dates are correlated with the date 41,300 ± 1000 BP (GIN-436), obtained from the peat layer under the Golovnin Volcano tephra (Melekestsev *et al.* 1988). The ^{14}C date of 32,300 ± 500 BP (GIN-8434) is obtained from the upper peat layers of the same outcrop.

Outcrop 3995 includes a series of ash layers, peat layers and alluvial sands with pebbles in the upper part. The pollen assemblage is characterized by a high quantity of herb pollen (up to 32.6%) and spores (up to 28.9%); tree pollen and shrubs composed 38.5–59.7% of the total sum, with dominating broadleaf taxa and an admixture of some small-leaved taxa. Conifers are represented by *Pinus* subg. *Haploxylon*. Among herbs, the *Cyperaceae* and *Gramineae* predominate. Ferns predominate among the spores. The zone *Quercus-Betula* is chosen by the pollen assemblage, which shows the presence of dominating broadleaf forests. The climatic conditions were warmer than at present. The ^{14}C date from the peat is 31,000 ± 1200 BP (GIN-8622). The ^{14}C value of >30,000 (GIN-5839) from the forest, buried by pyroclastic flow, yields a limit to the age for the last intensive Late Pleistocene eruption of the Golovnin Volcano. The ^{14}C date from peat buried by the Mendeleev Volcano tephra is in agreement with our data (Polunin 1969).

Holocene Events

Kunashir Island was connected to Hokkaido Island at the beginning of the Middle Holocene. The migration of warm and cold currents had a great impact on the dynamics of the natural processes in this region during periods of global climatic change. The birch assemblages changed to dominating broadleaf forests *ca.* 7000–6500 BP. The maximum warming on Kunashir Island was during the Atlantic period of the Holocene and is dated at 6520–5000 BP. This warm stage correlates with the climatic stage of Early Jomon in Japan and with the Holocene Optimum on Sakhalin Island and Primorie (Korotky *et al.* 1995; Sakaguchi *et al.* 1985). The average annual temperature was 2–3°C higher than present. Dominating broadleaf forests were widely spread in the southern and middle parts of Kunashir Island. Coniferous-broadleaf forests occupied the northern part of Kunashir. The cooling during the second part of the Atlantic (5700–5800 BP) was accompanied by a small sea-level regression and the development of *Alnaster* taxa at the coasts and in river valleys. Marine deposits from the section on Lagunnoe Lake, covered by peat, were dated as 6520 ± 110 BP (GIN-8340). This means that the sea level was *ca.* 2.5–3 m higher than at present. At this time, the Kunashir Island coast became dismembered. There were deep inlets and shallow straits instead of low isthmuses. The formation of lakes took place in river mouths due to active abrasion and formation of barriers. The lakes probably had some stages of irrigation and swamping.

The cooling was dated at 4500–4700 BP and is confirmed by the dominating of *Paralia sulcata* var. *sulcata* in the diatom assemblage. A considerable sea-level regression in the Middle-Late Holocene correlates with this paleogeographical boundary. Dune fields were formed on the coasts of Kunashir at this time (Korotky *et al.* 1996). Coniferous-broadleaf forests were widely spread in the central part of the island during the period of Early Subboreal warming. Many representatives of warm-water diatom species such as *Actinocyclus octonarius* were observed in the coastal waters of Kunashir Island. The vegetation changed significantly during the second part of the Subboreal; the coniferous-broadleaf forest boundary moved southward. The northern coniferous-broadleaf forest boundary moved southward up to Sernovodsky Isthmus; most of the island territory was occupied by dark-coniferous forests with *Picea* dominating. Large amounts of detrital material entered the coastal zone during Subboreal transgressions with accumulations in inlets. The Subboreal-Subatlantic cooling was accompanied by a sea-level regression. At this time the isthmus areas increased and swamps were formed in the coastal plains. Lakes and coastal dunes were formed at inlets and lagoons. The climate warming, accompanied by a transgressive phase in the Subatlantic, is confirmed by an increase of broadleaf pollen species. Evidence of a sea-level lowering after the Subatlantic transgressive phase was found in a peat layer at a depth of 0.6 m below modern sea level. A ^{14}C date of 850 ± 50 BP (GIN-8428) from this peat indicates the end of the transgressive phase. The cooling and smaller regression during the Little Ice Age period are characterized by intensive eolian accumulation, as shown by dunes and eolian covers on buried soils with ^{14}C dates of 290 ± 60 BP (GIN-7870) and 190 ± 40 BP (GIN-7886).

Conclusion

Global climate changes and the migration of warm and cold currents are visible in the dynamics of the natural environment at Kunashir Island. A Late Pleistocene interstadial (42,000–30,000 BP) is characterized by coniferous forest development, and the climate was cooler than today. Several caldera-forming eruptions of the Golovnin and Mendeleev Volcanoes occurred at this time. The Last Glacial Maximum sections do not contain material for ^{14}C dating. The dry and cool climate changed to warm and moist *ca.* 7000–6500 BP, a little later than on Hokkaido Island. At this time, the Kuroshio warm current became more active and moved toward the coast of Kunashir Island. The birch assemblages on Kunashir Island were replaced by broadleaf forests. During the Atlantic-Subboreal cooling (4560–4780 BP), the island vegetation changed slightly because of the influence of the warm current. A large sea-level regression for the Middle-Late Holocene occurred during this period. The cooling at *ca.* 3500–3000 BP led to strong vegetation changes, coniferous and broadleaf-coniferous forests occupied Kunashir Island. During the Subboreal-Subatlantic cooling (2080–1260 BP) the isthmus areas increased, coastal wetlands with lakes and coastal dunes were formed, and meadow and swamp landscapes developed. The large cooling was possibly connected with cold current influence. The Subatlantic warming (*ca.* 1000 BP) was not large. Active eolian accumulation took place during the Little Ice Age cooling and sea-level regression.

Acknowledgments

We thank Dr. L. P. Karaulova for providing the pollen analysis. We are grateful to colleagues from Kuril Natural Reserve for help during field work. We thank Dr. Ya. Kuzmin for correction of the English. This study was supported by the Russian Fund of Fundamental Investigation, Grants 95-05-15309, 97-05-65362 and 97-05-74616.

References

Bulgakov, R. F. 1993 New data about Quaternary history of southern islands of Kuril Ridge. Preprint by *Vestnik, Geographical Series*. Moscow State University. Dep. VINITI 2490-B93: 21 p. (in Russian).

Korotky, A. M., Razjigaeva, N. G., Grebennikova, T. A., Ganzey, L. A., Mokhova, L. M., Bazarova, V. B. and Sulerzhitsky, L. D. 1995 Holocene marine terraces of Kunashir Island, Kuril Islands. *The Quaternary Research* (Japan) 34(5): 359–375 (with Japanese abstract).

Korotky, A. M., Razjigaeva, N. G., Grebennikova, T. A., Ganzey, L. A., Mokhova, L. M. and Bazarova, V. B. 1996 Coastal dunes – indicator of global cooling, Kunashir Island, Kuril Islands. *Pacific Geology* 15(l): 53–59 (in Russian with English abstract).

Melekestsev, I. V., Braitseva, O. A., Erlikh, E. N., Santser, A. E., Chelebaeva, A. I., Lupikina, E. G., Egorova, I. A. and Kozhemyaka, N. N. 1974 *Kamchatka, Kuril and Komandar Islands: History of Development of Relief of Siberia and Far East*. Moscow, Nauka: 439 p. (in Russian).

Melekestsev, I. V., Braitseva, O. A. and Sulerzhitsky, L. D. 1988 Catastrophic explosive eruptions of volcanoes of the Kuril-Kamchatka region at the end of the Pleistocene – beginning of the Holocene. *Proceedings of the Russian Academy of Sciences* 300(1): 175–181 (in Russian with English abstract).

Polunin, G. V. 1969 Concerning the absolute age of the high terrace and Mendeleev Volcano on Kunashir Island. *Bulletin of Volcanological Stations Siberian Branch of USSR Academy of Sciences* 45: 53–55 (in Russian).

Sakaguchi, Y., Kashima, K. and Matsubara, A. 1985 Holocene marine deposits in Hokkaido and their sedimentary environments. *Bulletin of the Department of Geography, University of Tokyo* 17: 1–17.

Vorobiev, D. P. 1963 *Vegetation of Kuril Islands*. Moscow-Leningrad, USSR Academy of Science Press: 92 p. (in Russian).