Jour. Fac. Sci., Hokkaido Univ., Ser. VII (Geophysics), Vol. 8, No. 1, 15-27, 1986.

Palaeoenvironment in St. Lawrence Island, Alaska

Kinshiro Nakao and Kazuhisa Chikita

Department of Geophysics, Faculty of Science
Hokkaido University, Sapporo 060, Japan

Shyu Nakaya

Department of Earth Science, Faculty of Science
Hirosaki University, Hirosaki 036, Japan

Koichi Urakami

Applied Hydrodynamics, Faculty of Engineering
Hokkaido University, Sapporo 060, Japan

and

Yoshiyuki Ishii

Department of Geophysics, Faculty of Science
Hokkaido University, Sapporo 060, Japan

(Received November 9, 1985)

Abstract

The island is situated about 250 km to the south of Bering Strait at latitude 63°20′N and longitude 170°15′W in Bering Sea. The continental shelf of Bering Sea is bounded by a deep sea about 780 km to the south of the island. This boundary was the southernmost coast of the Bering-Chukchi Plateau or the so-called Beringia, which used to connect Alaska and Siberia as a land bridge 1,500 km wide, but was submerged when a postglacial transgression caused the sea level to rise about 10,000 years before present.

The environment of the middle terrace 60 m above sea level around the Pon To* was inferred from the significant change of facies throughout the Pon To core; namely, debris ground has been widely covered with a tundra since 2,500 years B.P. Furthermore, from the result of examination of the vertical profiles of particle density and ignition loss for the Pon To core, it was judged that the appearance of tundra started at the middle terrace since about 6,000 years B.P., accompanying an increase

* "Pon To" is the name given by Nakao, as it means "small lake" in the language of the Ainu, the native people of Hokkaido Island; and other lakes were likewise named Tanne To (oblong lake), Aratchi To (gentle lake), Poro To (large lake), Onne To (noble lake), Omu To (dammed lake) and Arara To (beautiful lake).

in ignition loss and a decrease in particle density.

On the other hand, it follows clearly from the vertical profiles of sodium concentration throughout the Pon To core that an increase in concentration in shallow depths corresponds to the marine transgressions which have taken place since 6,000 years B.P. and that small concentrations in deeper depths coincide with the marine regression during Glacial Interval.

1. Introduction

Recently, the general opinion favors the stand that, as the secular oscillation of solar radiation triggers either expansion or reduction of an ice sheet, a feedback effect is produced with respect to the ice sheet, causing either phenomenon to continue further, which is considered important in explaining drastic climatic changes during the Ice Age and Interglacial Age (Oerlemans, 1980, Pollard, 1983 and Flohn, 1974).

The northern and the southern hemisphere differ greatly in distribution of land and water in high latitudes. The former allows the continents around the Arctic Sea to provide a field for the continental ice sheet to spread (positive feedback), whereas the latter keeps constant the area of the ice sheet of the Antarctic Continent surrounded by the Antarctic Sea of ablation area.

The further elaboration of the ice-sheet model calls on us to look into a vapor supply to the ice sheets including the Laurentide, the Siberian and the Scandinavian Ice Sheet, to gather quantitative paleorecords on precipitation and air temperature and to examine the hydrological regime globally through the glacial and interglacial intervals.

The expedition was planned and conducted for "the Scientific Research in Hydrological Regime and Climatic Changes in the Arctic Circle", choosing St. Lawrence Island in Bering Sea to find out the feature of a vapor supply from the sea and examine its climatic effect when the continental shelf emerged widely in the Ice Age.

The island is situated about 250 km to the south of Bering Strait, at latitude 63°20′N and longitude 170°15′W in Bering Sea. It is 4,900 km^2 in area, where a tundra plain accounts for 70.8% and a mountainous region including the Kookooligit Mountains which culminate to 673 m above sea level occupies the remaining area.

The continental shelf of Bering Sea is bounded by a deep sea about 780 km to the south of the island. This boundary was the southernmost coast of the Bering-Chukchi Plateau or the so-called Beringia, which used to connect Alaska and Siberia as a land bridge 1,500 km wide, but was submerged when a

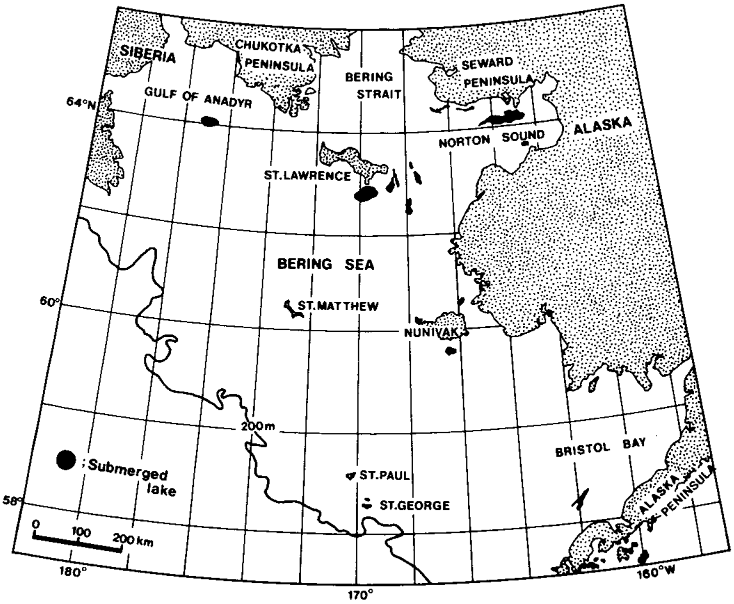


Fig. 1 Location map of St. Lawrence Island, thick line indicated the southernmost shore line in the Beringia.

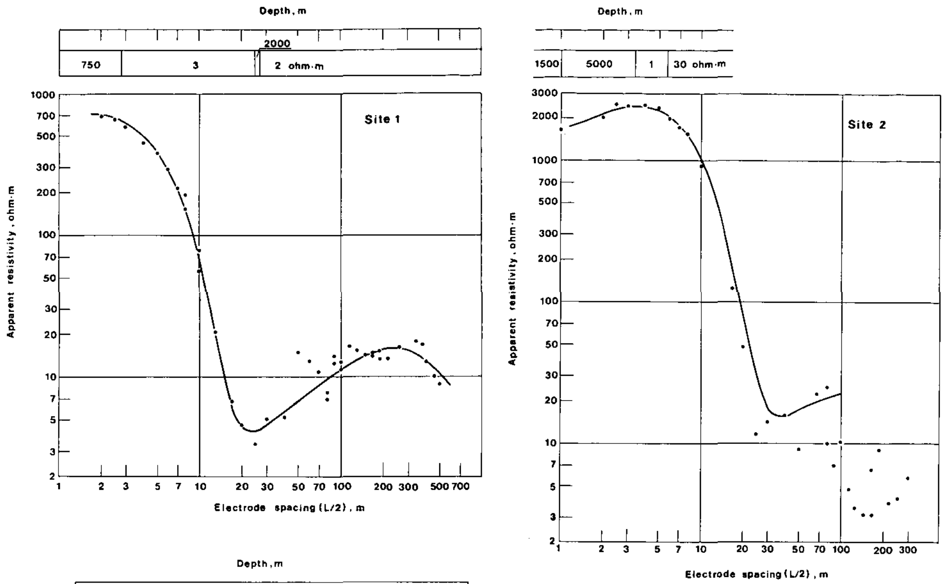
postglacial transgression caused the sea level to rise about 10,000 years before present (Fig. 1).

The island is characterized by the presence of continuous permafrost and an oceanic climate with only a slight difference in air temperature between summer and winter, in marked contrast with Fairbanks in interior Alaska, the mean annual air temperature and the annual precipitation being respectively −3.5℃ and 568 mm at Gambell, −4.9℃ and 270 mm at Savoonga.

2. Sedimentary structures inferred from electrical depth soundings

Three locations were selected as sites 1, 2, 3 for electrical depth soundings on a sand bar bordered between the Koozata Lagoon and the sea. Field data were analyzed by matching the field curves to the suitable theoretical curves for multiple strata using a computer technique.

Investigations at sites 1, 2, 3 indicated that an unsaturated thin layer having the resistivities of $10^2 \sim 10^3$ ohm • m lay in depths shallower than 3 m and that permafrost did not exist because of the thermal effect of such a large water body as the lagoon and sea (Fig. 2).



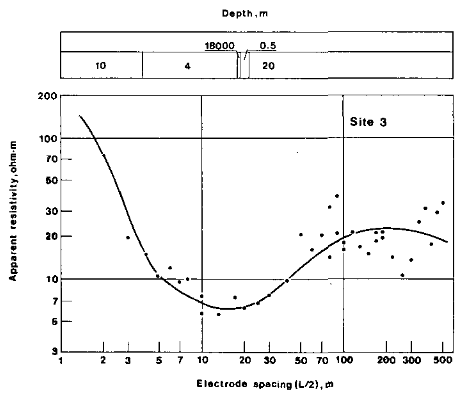


Fig. 2 Apparent resistivity curve measured by Schlumberger configuration at three locations of sites 1, 2, 3 on the sand bar bordered Koozata Lagoon and sea in August 1983. Evaluated resistivity-depth column is shown in the upper part of the figure.

Other locations were selected in a tundra plain; namely, site 4 near the Koozata Lagoon, and site 5, 6 near Savoonga Village. Investigations at sites 4, 5, 6 showed that the base of permafrost extended to the depths ranging from 14 to 27 m (Fig. 3). The depths are much shallower than the calculated values reported by Nakao et al. (1986) on the basis of mean annual air temperature.

3. Palaeoenvironments inferred from the lake sediments cored in Pon To and Koozata Lagoon

Cored samples were collected in two lakes, one at the Pon To and the other

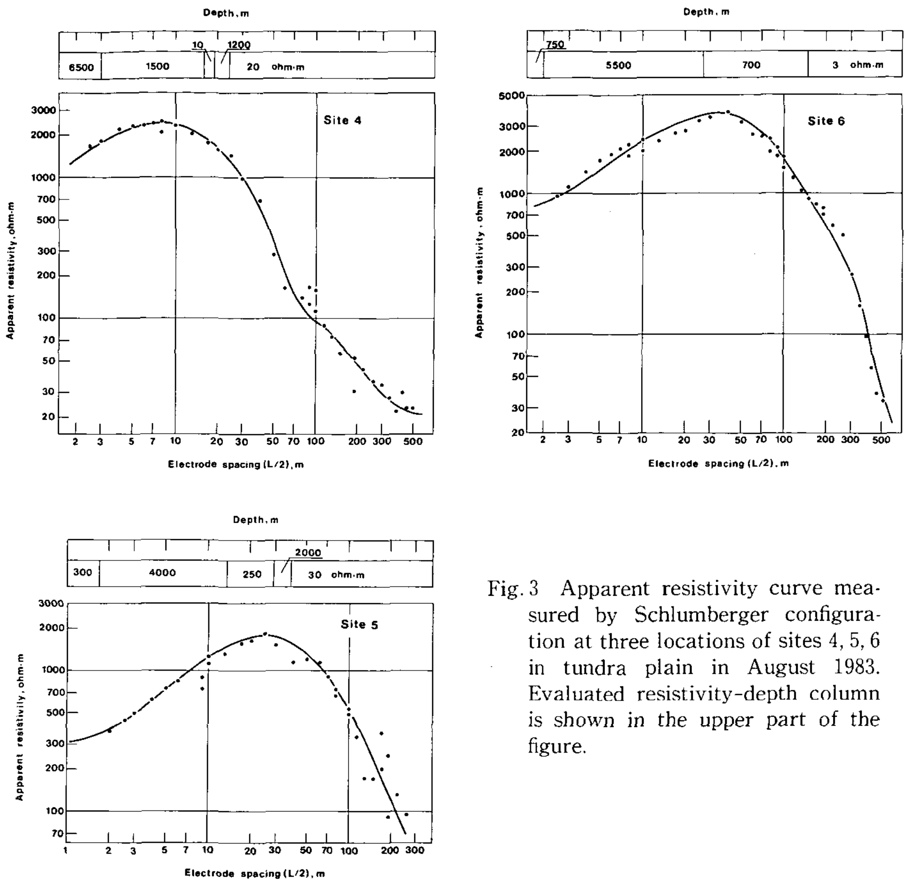


Fig. 3 Apparent resistivity curve measured by Schlumberger configuration at three locations of sites 4, 5, 6 in tundra plain in August 1983. Evaluated resistivity-depth column is shown in the upper part of the figure.

at the Koozata Lagoon as shown in Fig. 4. The former is located in a tundra plain with the middle terrace 60 m above sea level, while the latter is a coastal and brackish lagoon.

The corer used was a piston core sampler of the modified type, which has a device using a locking and releasing mechanism for the movement of the piston, whereby corings were conducted on the platform with a triangle jointed by aluminum pipes aboard two rubber boats.

Core samples obtained were 272 cm long in the Pon To of 52 cm in water depth, and 156 cm long in Koozata Lagoon of 3 m in water depth, with their facies shown in Figs. 5, 6.

When the Pon To core obtained was examined, it was clearly shown from a geologic log that the facies changed markedly from a silty clay to a peat

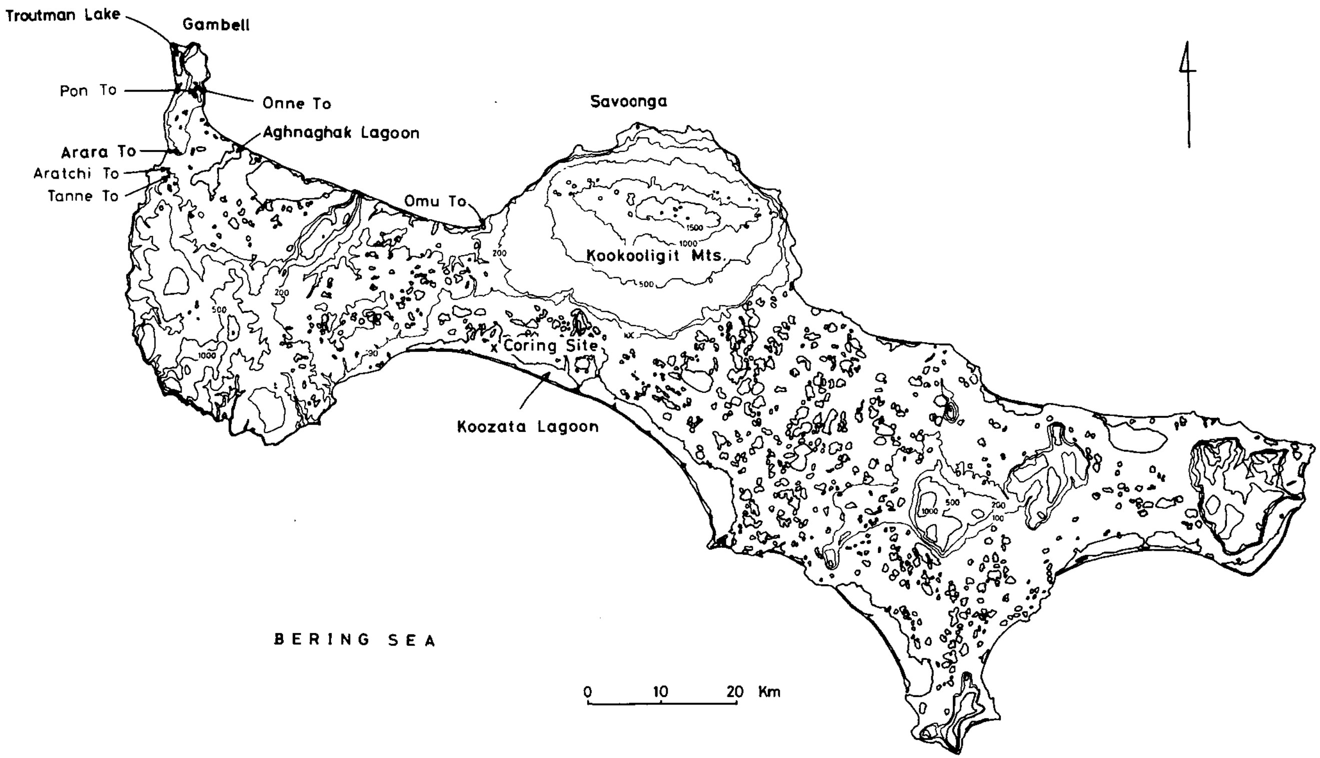


Fig. 4 Topographic feature and the surveyed area in St. Lawrence Island.

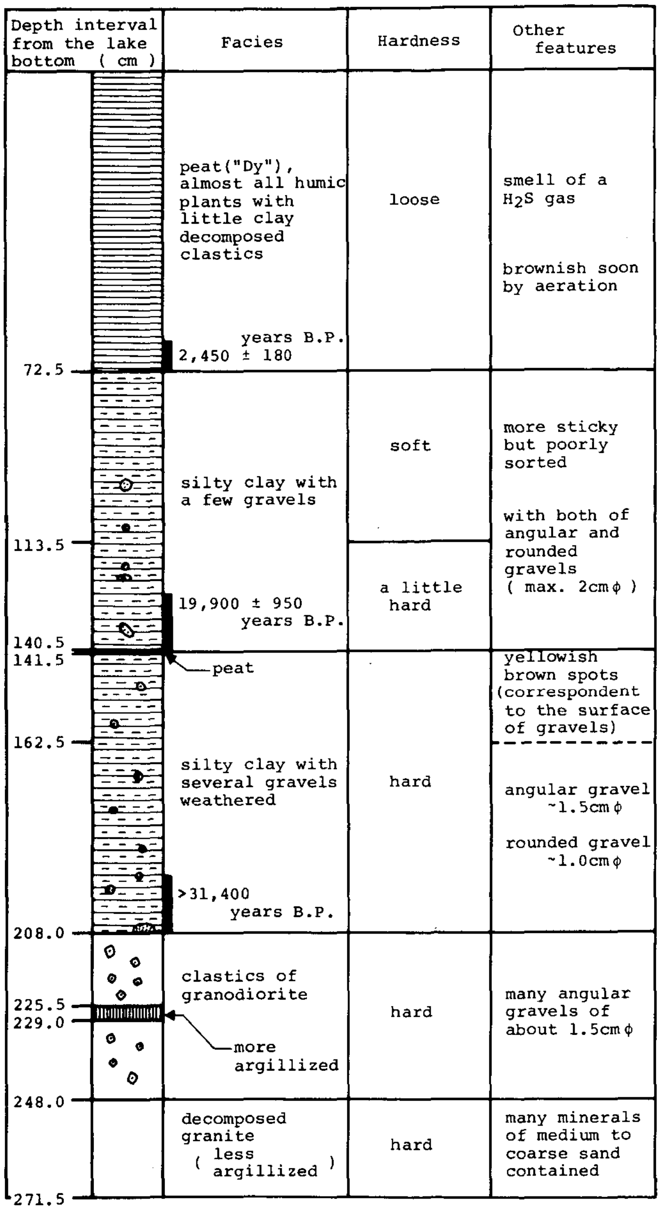
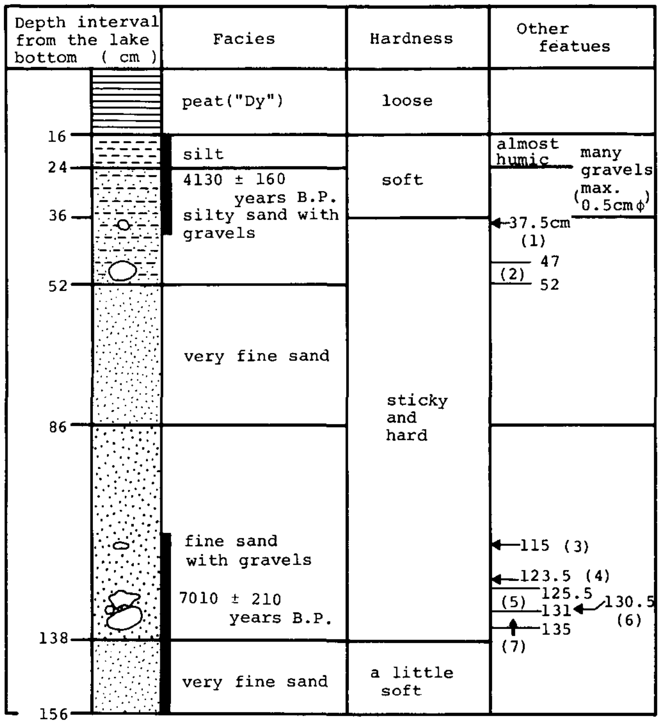


Fig. 5 Geologic log for bottom sediments cored at Pon To.



Remarks, (1) : rounded gravel of 2cm φ
(2) : rounded gravel of 5cm φ
(3) : angular gravel of 2.5cm φ
(4) : many fragments of shells of *Diplodonta sp.*
(5) : large angular gravel
(6) : angular gravel of 1cm φ
(7) : large sub-rounded and platy gravel

Fig. 6 Geologic log for bottom sediments cored at Koozata Lagoon.

sediment above the core depth of 72 cm. Meanwhile, the radiocarbon ages determined by Teledyne Isotopes in Westwood, New Jersey, were 2,450 years B.P. at the core depths between 66 and 71 cm ; 19,900 years B.P. between 127 and 139 cm and over 31,400 years B.P. between 196 and 208 cm.

The environment of the middle terrace around the Pon To was inferred from the significant change of facies; namely, debris ground has been widely covered with a tundra since 2,500 years B.P. Furthermore, from the result of examination of the vertical profiles of particle density and ignition loss for the Pon To core as shown in Fig. 7, it was judged that the appearance of tundra started at the middle terrace since about 6,000 years B.P., accompanying an increase in ignition loss and a decrease in particle density.

Throughout the Koozata Lagoon core, the facies show the tendency of an

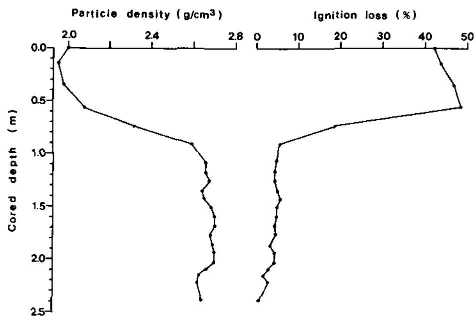


Fig. 7 Vertical profiles for particle density and ignition loss throughout core samples of Pon To.

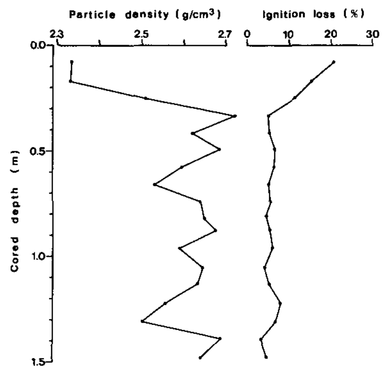


Fig. 8 Vertical profiles for particle density and ignition loss throughout core samples of Koozata Lagoon.

increase in the contents of gravels with increasing depth through the sandy sediments under a thin peat stratum as shown in Figs. 6 and 8. This tendency of becoming coarser corresponds to a marine transgression about 6,000 years B.P.

4. Chemical characteristics of inland water and sediment cores

Main chemical elements in lake water, river water and patched snow were determined by using the portable chemical analyzer of Hach and the Hitachi 180-50 atomic absorption spectrophotometer, with the results shown in Tables 1 and 2 respectively.

As for chemical characteristics of salts from marine sources, slight increases are shown in electric conductivity and concentrations of sodium, magnesium and calcium of lake water near the Pon To.

A selective chemical leaching method was used to analyze chemical elements in cored sediments as shown in Fig. 9.

The dried samples of about 0.2~0.4 g at 100℃ were digested in 30 ml of distilled water for 24 hours at room temperature to dissolve water soluble salts in sediments (fraction A). After the dissolution of the water soluble salts, the suspension was separated from the water by centrifuging. The residue from the specimen treated with water was digested in 30 ml of 1 M, CH_3COOH solution for 4 hours at room temperature (fraction B). The chemical constitutents in fraction B were regarded as associated with carbonate. The residue from the specimen treated with acetic acid was digested in 30 ml of 1 M,

Table 1 Chemical composition of water samples collected in St. Lawrence Island, July 1982.

Sampling site	pH	Electric conductivity (μmhos/cm)	Element (mg/l)				
			Cl^-	Hardness	SO_4^{2-}	Fe	NH_4^+
Troutman Lake 1	6.2	248	63	20	8	0.08	0.15
〃 2	6.2	256	59	30	8	0.10	0.31
〃 3 0 m	5.9	235	60	31	6	0.10	0.26
3 m	5.7	237	60	31	8	0.11	0.18
Swamp	6.4	86	25	18	6	0.17	0.15
Inlet river	6.5	50	10	15	12	0.05	0.13
Tanne To	6.4	28	10	4	trace	0.50	0.58
Aratchi To	6.6	75	20	13	trace	0.20	0.46
Poro To (near Onne To)	6.9	250	48	42	11	0.20	0.77
Onne To	6.6	150	27	31	5	0.10	0.42
Aghnaghak Lagoon							
lake shore	6.7	4800	1050	—	90	0.75	0.50
200 m offshore	6.6	—	1640	543	100	0.50	0.50
Koozata Lagoon A	7.3	197	40	18	9	0.35	—
〃 B	7.2	1620	450	140	44	0.23	—
〃 C	7.8	1570	420	151	43	0.51	—
Inlet river	7.1	27	5	6	trace	0.10	—
Omu To	7.1	580	156	48	14	0.22	—

Table 2 Chemical composition of water samples collected in St. Lawrence Island, July and August 1983.

Location	Element (mg/l)			
	Na	K	Mg	Ca
Onne To	17.0	0.75	5.41	4.04
Arara To	11.6	0.66	2.34	1.83
Omu To	241	8.80	27.9	8.48
Inlet river	6.01	0.55	1.43	0.74
Koozata Lagoon	550	21.0	51.0	16.7
Inlet river 1	5.79	0.57	1.40	0.77
〃 2	33.1	1.23	3.61	2.76
Savoonga River	5.41	0.19	2.17	1.29
Small pond (at Savoonga)	8.60	0.39	1.72	1.03
Patched snow	1.94	0.20	0.12	0.02

NH_2OH-HCl in 1 M, CH_3COOH solution for 4 hours at room temperature (fraction C), which was regarded to contain hydroxides, oxides and a part of unstable sulfides. The residue from the specimen treated with hydroxylamine

Sample (-80 mesh, $0.2-0.4$ g)
— H_2O, 30 ml, 24 hrs., Stirring
Centrifuge (3500 r.p.m., 15 min.)

A fraction — Residure
— 1 M, CH_3COOH, 30 ml, 4 hrs.
— Centrifuge (3500 r.p.m., 15 min.)

B fraction — Residure
— 1 M, NH_2OH-HCl in CH_3COOH, 30 ml, 4 hrs.
— Centrifuge (3500 r.p.m., 15 min.)

C fraction — Residure
— 1.2 M, HCl, 30 ml, 2 hrs. at 100°C
— Centrifuge (3500 r.p.m., 15 min.)

D fraction — Residure
— HF, HNO_3, $HClO_4$

E fraction

Fig. 9 Selective chemical leaching procedure.

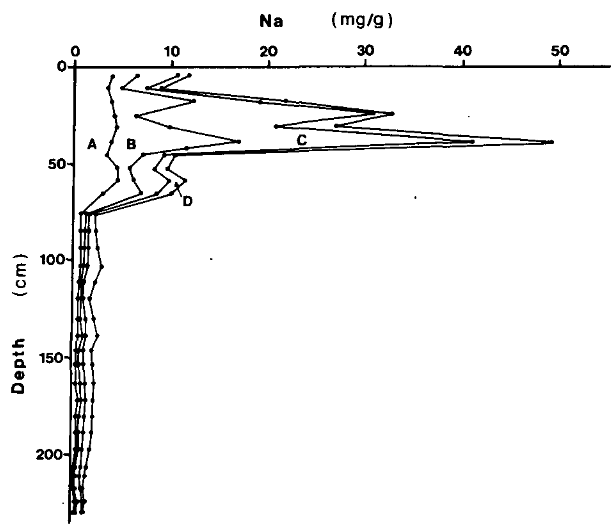


Fig. 10 Vertical profiles of sodium concentration in Pon To core.

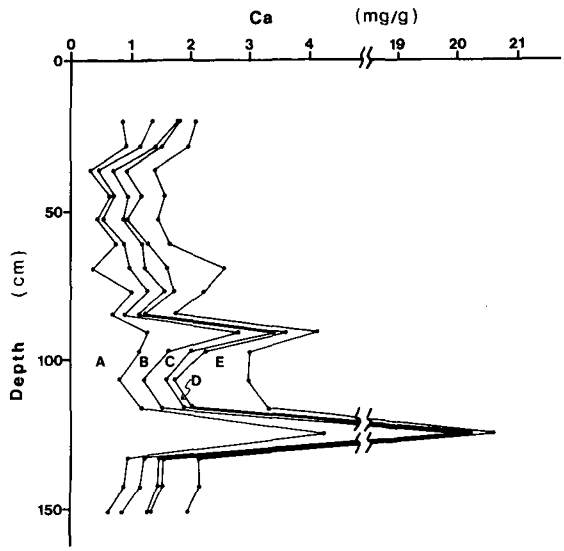


Fig. 11 Vertical profiles of calcium concentration in Koozata Lagoon core.

was digested in 30 ml of 1.2 M, HCl for 2 hours at 100℃ (fraction D), which contained unstable clay minerals and a part of sulfides. The final residue was decomposed with a mixed solution of $HClO_4$, HNO_3 and HF (fraction E), which contained stable silicates.

The chemical elements of each fraction were determined by using the Hitachi 180-50 atomic absorption spectrophotometer for the main elements and the Hitachi Z-7000 Polarized Zeeman atomic absorption spectrophotometer for the trace elements.

It follows clearly from the vertical profiles of sodium concentration throughout the Pon To core that an increase in concentration in shallow depths corresponds to the marine transgression which have taken place since 6,000 years B. P. and that small concentrations in deeper depths coincide with the marine regression during Glacial Interval when the precipitation of a marine salt decreased with the receding shoreline to 780 km far from the present site (Fig. 10).

On the other hand, from the examining of calcium concentration in the Koozata Lagoon core, it may be judged that the increases in deeper strata are attributable to the direct effect of the marine transgression (Fig. 11).

Acknowledgements

The writers wish to express their hearty thanks to President P. Apangalook, of Gambell Native Corporation and President B. Gologergen and Ex-President P. Rookok, of Savoonga Native Corporation for their kind logistic support in the island; Mr. R. Antoghame and Mr. E. Noongwook, who served as guides, for their assistance in field work in the island.

They should finally like to extend their gratitude to other expedition members; Professor E. Tokunaga of Faculty of Economics, Chuo University, Associate Professor R. Tanoue of Asahikawa Technical College, Dr. Y. Maeda of Kobe City Institute for Educational Research and Dr. J. LaPerriere of Institute of Water Resources, Alaska University, for their earnest assistance in field work, and Associate Professor T. Fujiki of Department of Geophysics, Hokkaido University, for his beneficial discussion on climatic changes of Alaska.

The expense of the field expedition and the resulting study was defrayed by Grant in Aid for Overseas Scientific Survey (Overseas Scientific Expedition "Hydrological Regime and Climatic Changes in the Arctic Circle") of the Ministry of Education, Science and Culture of Japan.

References

Flohn, H., 1974. Background of a geophysical model of the initiation of the next glaciation. Quaternary Research, **4**, 385-404.

Nakao, K., Y. Ishii, K. Urakami and J. LaPerriere, 1986. Hydrological regime in tundra plain, St. Lawrence Island in Bering Sea. Jour. Fac. Sci., Hokkaido Univ., Ser. VII (Geophysics), **8**, 1-13.

Oerlemans, J., 1980. Continental ice sheets and the planetary radiation budget. Quaternary Research, **14**, 349-359.

Pollard, D., 1983. Ice-age simulations with a caving ice-sheet model. Quaternary Research, **20**, 30-48.