Studies on the Soils Derived from Volcanic Deposits in Tomakomai District*

By

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苫小牧地方における火山堆積物に由来する土壌の研究*

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Introduction

Japan, located in the west of the Circumpacific Volcanic Zone, has been often subjected to the great volcanic eruptions since the Epoch of Neocene. Therefore, over 16 percent of the whole land (370,000 km^2) is said to consist of black soils (Ando soils, Andosols) developed from the eruptive deposits. Besides, there are also a lot of lands covered with immature soils (Regosols or Entisols), which are made up of new volcanic ashes, pumices or lava flows brought about from active volcanoes. Tomakomai district, south of the central part in Hokkaido which is the second largest island of an area next to the main land, Honshu, is the greatest region in the distribution of the immature soils in Japan.

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Tomakomai Experiment Forest, having an area of 2,720 ha, is situated on the hillside of the district and only 4 km to the coast of the Pacific Ocean. The forestlands are all occupied with unsufficiently weathered volcanic ashes, ejected from Mt. Tarumae only 240 years ago. Therefore, the soils are so infertile excluding a shallow A horizon, that the productivity of the lands is low. The severity of the soil conditions naturally seems to retard considerably the growth of the trees and result in the difficulty of the forest management to a large extent. However, since the Experiment Forest established in 1904 lies near Sapporo City, the locality of Hokkaido University, it has been intensively used for the activities of the forest researches and student trainings for a long time.

The present studies carried out mainly in the Experiment Forest, deal with the properties of the soils in the natural and man-made forest stands and the wood and foliage analyses of trees as well as the growth of the planted Todomatsu-fir (*Abies sachalinensis*) by stem analysis, and moreover the characteristics of buried soils obtained by chance. Though the buried soils have been investigated for the geological study[3,4,9] and the tephrochronology[2,10,12,13] by a radiocarbon dating method in detail, the relic soils composed of several formations involving some 20 layers are also pedologically interesting and useful for the research of pedogenesis. It might be understandable by making the investigation, how long it would take for the recent soils derived from the last eruption covering the district to develop to mature soils, and how the states of the land had been in the past individual times.

The parts of the present studies have been announced in the meetings of Hokkaido Branch of Japanese Forestry Society.[14~16]

The author is deeply indebted to ex-Lecturer Y. MAEDA and the members of Tomakomai Experiment Forest for their assistance during the course of the experiments, and would heartily express his appreciation.

Outlines of the District

1. General Description

This district belonging administively to Tomakomai City lies in the southern part of Ishikari-Yuhfutsu lowlands (Sapporo-Tomakomai depression) and is situated in 42°36′ north latitude and 141°36′ east longitude. It covers an area of approximately 568 km^2 and comprises a population of around 150,000. Tomakomai founded in 1873, had been a small fishing village before Ohji Paper Mill was constructed in 1909. After World War II, Tomakomai City has been changed on a large scale to a coastal industrial city under Japanese Land Development Planning, and also the east seaport is being constructed in addition to the present west harbor. Tomakomai is now one of the prominent cities in Hokkaido. The habitants are, however, anxious about the influence of air pollutants emitted by large factories and a large number of automobiles on highways. The Experiment Forest becomes increasingly necessary for the people looking for a healthy and recreational place. Its activities have been expanded to the studies on urban forest, wild life and air pollution.

The district is topographically divided into two lands: One holding about 70 percent of the total area is a highland accumulated with thick volcanic ejecta in the northern side including the top of Mt. Tarumae (1023.8 m). The other is a lowland composed of thick peats and volcanic ejecta in the south eastern side including the urban area. The Experiment Forest is located in the south end of the highland.

Table 1. Climatological data of Tomakomai Experiment Forest

		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
Temperature (°C)	Mean	− 7.1	− 5.5	− 2.0	4.4	9.4	14.3	18.9	20.9	15.8	9.1	2.7	− 3.5	6.5
	Mean Max.	− 0.7	0.2	3.0	9.3	14.7	18.4	22.3	24.7	21.1	15.2	8.2	2.4	11.6
	Mean Min.	−14.5	−13.2	− 8.3	− 1.9	8.3	10.2	15.3	16.6	9.7	2.4	− 3.4	−10.2	0.5
	Max.	7.1	7.9	12.1	21.0	27.0	27.7	32.3	33.1	26.5	24.3	17.6	11.6	
	Min.	−26.0	−30.4	−21.6	−14.0	−7.8	−0.6	2.2	5.8	−0.3	−7.6	−13.1	−23.0	
Relative humidity (%)		74.4	71.8	73.2	73.0	76.7	83.7	85.1	84.3	80.7	78.4	76.3	75.7	77.8
Precipitation (mm)		90.2	58.8	78.2	91.2	128.7	145.3	140.6	168.1	201.6	164.0	121.5	56.8	120.4 (1445)
Sunshine time (hr.)		124.6	129.9	160.3	167.7	169.2	125.9	113.2	124.5	142.8	142.6	108.2	114.1	135.3
Sunshine rate (%)		42.4	48.4	43.4	42.4	37.6	27.8	24.6	29.2	38.3	41.0	36.9	40.4	37.3
Wind speed (m/s)		1.6	2.0	2.1	2.5	2.5	2.3	1.8	1.7	1.8	1.8	1.7	1.5	1.9
Prevailing direction		N	N	N	NNW	SSW	S	S	S	N	NW	NNW	NNW	

The figure in parenthesis is the yearly precipitation.
1. Observed period: 10 years from 1970 to 1979.
2. Observed location: The forest at the height of 19 m above sea level.

Concerning the climate, the mean monthly climatological data recorded at the Tomakomai Experiment Forest[6] are presented in Table 1. The annual mean temperature is 6.5°C and significant difference between cold and warmth is recognized, while according to Tomakomai local meteorological observatory in 1979, the temperature of the urban area is 7.2°C and this difference is not so remarkable due to standing on the seaside. Total yearly precipitation is 1,445 mm, about 70 percent of which comes down during the five months of vegetation growing period. Generally, snow begines to fall in the beginning of November and snowcovers melting nearly by the end of next March, are not so thick that the soils are frozen to some 60-cm depth below ground till middle April. Meanwhile, late heavy frosts occur sometimes even in the end of May, and injure the young tree buds just unfolded in the planted forests. Sunshine times seem comparatively short owing to the sea fog often visiting during a summer season. Though the data show a wind force is weak, typhoons or storms of maximum speed more than 30 meters per second have stricken the district at the rate of once in 10 to 15 years at least for the past 75 years.[11]

Both the typhoons of 1954 and 1981 have seriously caused a great damage to this district including Tomakomai Experiment Forest. These bad climatic conditions naturally affect the growth of the trees in the Experiment Forest together with those soil conditions.

2. Geological Features[12]

Original form of the Japan Islands is supposed to have been completed by the end of Neocene Epoch. Entering Pleistocene, there come alternative glacial and interglacial stages in the earth, so that the Pacific Ocean appears to connect with the Sea of Japan through the so-called old Ishikari straits in some 40 thousand years before Present (B. P.), and on the contrary a great plain in the district seems to be made by a 100-meter drop of the sea level in the maximum Würm stage owing to the eustatic changes. In these ages {about 32,000 years B. P. as determined by the carbon-14 dating of chared Ezomatsu-spruce (*Picea jezoensis*) in the buried fossil forests} there happens a drastic eruption of Shikotsu Volcano which has formed a great caldera, Lake Shikotsu, and accumulated the tuffaceous ejecta as much as a 30-m thickness in the district. After lowering slightly the sea level, the earth enters to Holocene, the warm climate age, in which the transgression seems to occur again in this area, as observed by shell mounds at the edge of the highland. In these times the volcanoes such as Mt. Eniwa (En) and Mt. Tarumae (Ta) begin to erupt and shower pumices and ashes on the land. Mt. Tarumae is an active volcano which has repeated the explosion making the formations from Ta-d to Ta-a not only in prehistoric age but even in the present days. Meanwhile, the land has been expanding due to the regression so as to achieve Yuhfutsu lowland by 3,000 years B. P. According to an old book, Tsugaru Hikan, volcanic activities of this mountain occurred in 1667 and 1739 A. D. and accumulated tremendous ejecta with thicknesses of 50 to 200 cm and 10 to 200 cm corresponding to Ta-b and Ta-a formations in this district, respectively. It can, accordingly, be said that the surface land of the district is composed of the formation of Ta-a including several fall units, together with deposits from the small scale eruptions of Mt. Tarumae after entering into the 20th century.

Experiments

1. Environmental and Soil Surveys

The surveys were carried out mainly in the Experiment Forest in 1970 to 1972. For comparison, the soils of Todomatsu-fir plantation grown most favorably, was investigated in the national forest under Shiraoi District Forestry Office locating in the 30-km west of Tomakomai City, though being different in the parent material, which is volcanic ash soils derived probably from the eruption of Mt. Usu. As shown in Fig. 1, the plots chosen were three from natural forests in the compartment 405, 326 and 423, and four from the fir plantations in 203, 409 and 138,

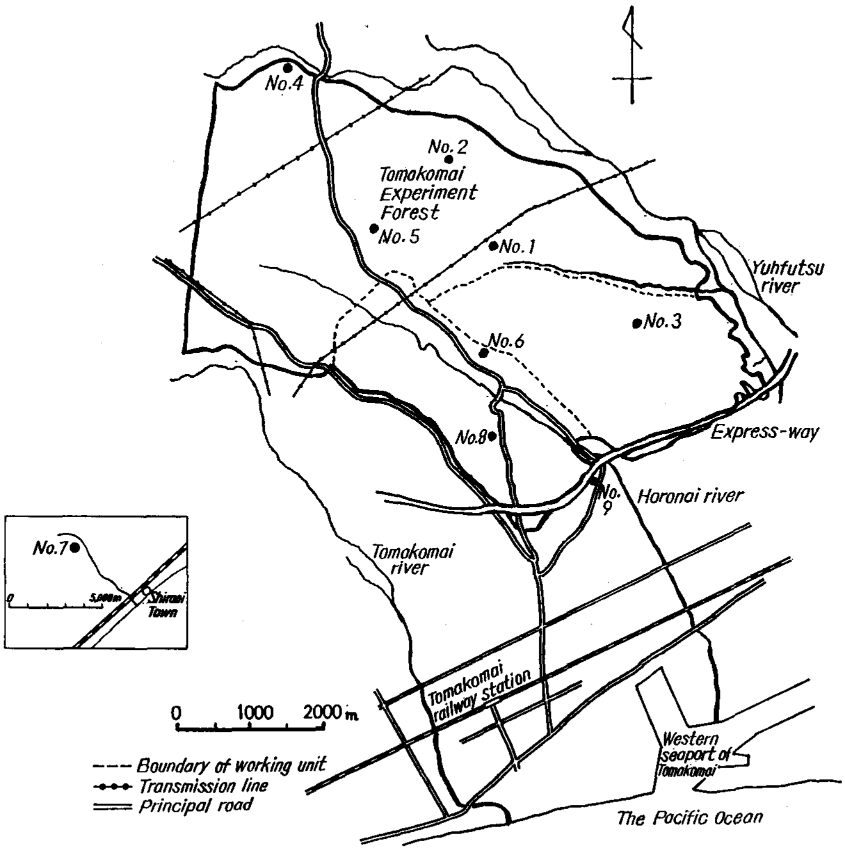

Fig. 1. Location of experimental plots in Tomakomai Experiment Forest.

as well as the Shiraoi national forest compartment 152, giving numbers from 1 to 7, respectively. The surveys of the buried soils were done in 2 sites of plot Nos. 8 and 9.

The investigated plots in the natural forests of Nos. 1, 2 and 3 are in the forest reserve, the stand damaged by the 1954-typhoon and the forest land covered almost with *Sasamorpha borealis*, respectively. After the trees and undergrowths were described in an area of 20 × 25 m around the plot, the pit was made up to 60 to 100-cm depth in accordance with fine roots of the trees. The soil profiles observed with naked eye were divided into 5 or 6 layers, which were given the Roman numerals from the top layer. Each layer was individually examined on thickness, color and texture. The samples were taken for the determination of moisture, apparent specific gravity and three-phase distribution in the field by a core sampler, and also collected for the analyses in the laboratory together with Ao layer matters. The leaves of main trees were collected in autumn for the foliage analysis.

The plots of the Todomatsu-fir planted stands are as follows: No. 4 is in the compartment 203, the north-western edge of the Forest, and is the stand planted in 1963 under a small area clear cutting system for the forest conversion from the natural forests. No. 5 is in 409 and the stand of the underplantation done in 1963, resulting from the wind-fallen by the 1954-typhoon. No. 6 is in the compartment 138, where the planting was carried out in 1937. No. 7 is in the plantation of the compartment 152 in the national forest and on the river bank along Shiraoi River. After the inventory was examined on the survived numbers and the growths, the soil profiles were made and investigated by the above-mentioned. The soil samples were collected in the same way. The typical Todomatsu-fir trees were felled in the plot of Nos. 6 and 7 and used for chemical analysis and stem analysis.

The plots of Nos. 8 and 9 are: The former was in a leasing site for Tomakomai City Water Plant in the compartment 120, and was digging for making a new reservoir. The latter was in a private land adjacent to the compartment 1, and was constructing a new gradient. This plot is on the coastal terrace composed of several formations including 18 to 20 layers. The soil surveys in the field were done in the same manners as above and the soil samples were collected.

2. Analyses

Soil analyses were done on the air-dried fractions passed through a 2-mm sieve (fine soils). All the data were recorded on an oven dry basis. As for the physical properties, mechanical analysis, bulk density, real specific gravity and maximum water holding capacity as well as pF values were examined, while pH, exchange acidity, carbon, nitrogen, cation exchange capacity (CEC), exchangeable cations (Ca, Mg, K and Na) and absorption coefficient of phosphoric acid were determined as for the chemical properties, including the analysis of Ao layer matters.[17]

Mineral components contained in Ao matters, IA and buried soils as well as the leaves of main trees were also investigated on silicon, aluminum, iron, magnesium, calcium, potassium, sodium, phosphorus and total nitrogen by the method reported in the previous studies.[1,17]

The typical Todomatsu-fir trees collected from the plot Nos. 6 and 7 were subjected to thorough stem analysis by Nakajima's method.[17] The rests of the trees divided into 6 parts, i. e. lower sapwood, lower heartwood, middle wood, top wood, bark and needle-leaves were milled and chemically analyzed by the standard procedure.[17]

Results and Discussion

1. Natural Forest Soils

Circumstances of the plot Nos. 1, 2 and 3 are shown in Table 2. As the district belongs to the southern Pan-Mixed Forest Zone, the intermediate zone between the northern Asiatic Temperate and Subarctic Zone, the forests are largely composed of broad-leaved trees such as *Quercus mongolica* var. *grosseserrata*, *Cercidiphyllum japonicum*, *Kalopanax pictus*, *Carpinus cordata*, *Fraxinus* spp., *Acer* spp., *Tilia japonica*, *Ulmus davidiana* var. *japonica*, *Phellodendron amurense*, *Betula* spp. *etc.*, mixed slightly with some conifers of *Picea jezoensis* and *Abies*

Table. 2. Circumstances of natural forests

Plot No.	Compartment	Slope and direction	Mensuration		Main tree species	Undergrowths	
			Stand density (stems/ha)	Growing stock (m^3/ha)		Species	Degree of cover
1	405	flat	1120	103.9	*Quercus mongolica* var. *grosseserrata*, *Cercidiphyllum japonicum*, *Kalopanax pictus*, *Carpinus cordata*, *Fraxinus lanuginosa*, *Acer mono*, *A. palmatum* var. *matsumurae*, *Sorbus alnifolia*, *Prunus sargentii*, *Tilia japonica*, *Alunus japonica*, *Ostrya japonica*, *Ulmus davidiana* var. *japonica*, *Magnolia obovata*, *M. kobus* var. *borealis*, *Cornus controversa*, *Phellodendron amurense*, *Acanthopanax sciadophylloides*, *Picea jezoensis*.	*Dryopteris crassirhizoma*, *Trillium smallii*, *Lilium cordatum* var. *glehnii*, *Maianthemum dilatatum*, *Pachysandra terminalis* *Phryma leptostachya* var. *asiatica*, *Daphne kamtschatica* var. *jezoensis*, *Rhus ambigua* *Hydrangea paniculata*, *Euonymus sieboldianus*, *Schisandra chinensis*.	# + + + + + + + + + +
2	326	S-18°	580	26.4	*Ulmus davidiana* var. *japonica*, *Cercidiphyllum japonicum*, *Carpinus cordata*, *Sorbus alnifolia*, *Acer mono*, *Quercus mongolica* var. *grosseserrata*, *Phellodendron amurense*, *Alnus japonica*.	*Diarrhena japonica*, *Phryma leptostachya* var. *asiatica*, *Sanicula chinensis*, *Polygonatum odoratum* var. *maximowiczii*, *Dryopteris crassirhizoma*, *Artemisia montana*, *Adenocaulon himalaicum*, *Senecio cannabifolius*, *Actinidia arguta*, *Morus bombycis*, *Aralia elata*.	# + + + + + + + + +

Plot No.	Compartment	Slope and direction	Mensuration		Main tree species	Undergrowths	
			Stand density (stems/ha)	Growing stock (m^3/ha)		Species	Degree of cover
3	423	flat	980	54.5	*Salix bakko*, *Quercus mongolica* var. *grosseserrata*, *Fraxinus lanuginosa*, *Sorbus alnifolia*, *Magnolia obovata*, *Acer mono*, *Tilia japonica*, *Cercidiphyllum japonicum*, *Cornus controversa*, *Ostrya japonica*, *Carpinus cordata*, *Kalopanax pictus*.	*Sasamorpha borealis*	⧻
						Schisandra chinensis,	+
						Lycopodium obscurum,	+
						Sanicula chinensis,	+
						Trillium smallii,	+
						Dryopteris crassirhizoma,	+
						Carex siderosticta,	+
						Erigeron anuus,	+
						Pachysandra terminalis,	+
						Symplocarpus renifolius,	+
						Rhus trichocarpa,	+
						Aralia elata.	+

sachalinensis, while the undergrowths mainly occupied in the forests are *Dryopteris crassirhizoma*, *Diarrhena japonica* and *Sasamorpha borealis etc*. However, the area of the forestland covered with *Sasa* species hindering the forest regeneration in Hokkaido is comparatively small in this district. Accordingly, the stand density is generally high but the growing stock is so low as 104 m^3 a hectare in the forest reserve at plot No. 1. The properties of the soils under natural condition are shown in Table 3. Within the profiles examined, the soils were divided into 4 to 5 layers, in which only the top layer was soft and mellow, mixing a considerable humus and was determined to belong to A horizon with a thickness of 6 to 16 cm, while the others were determined to belong to C horizons consisting of mostly gravels and sands. As the soils of the third or fourth layer contained a little quantity of humus and clay, it seems to have been the top layer of Ta-b formation ejected in 1667 A. D. Because the period was so short as 70 years, it is believed the top at that time was not almost weathered. Accordingly, the soil type is classified into immature soils (Im) or Regosols due to unfully developing the differentiation of the horizons. The amount of gravels contained is generally abundant, especially in the lowest layer, though the contents are different. Concerning the distribution of the three phases, gas space ratio is suitable for the air and water permeability.

The physical and chemical properties of fine soils together with those of Ao matters are shown in Table 4. The result of mechanical analysis shows that the amount of the silt and clay is very small. Therefore, the soil class belongs on the whole to S (sand) or LS (loamy sand). The air-dried moisture and the water holding capacity are naturally low excluding IA layer soil. As for chemical properties, the pH value inclines a little to acidity and carbon and total nitrogen

Table 3. Physical properties of natural forest soils under natural condition

Plot No.	Location (compartment)	Layer	Depth (cm)	Thickness (cm)	Color: Description of fresh soil with naked eye	Color: Fresh soil by Munsell	Color: Dried soil by Munsell	Apparent specific gravity: Fresh soil	Apparent specific gravity: Dried soil	Moisture content based on: Fresh soil (%)	Moisture content based on: Dried soil (%)	Gravel (%)	Distribution of three phases in soil (Vol. %): Solid	Liquid	Gas	Porosity (Vol. %)
1	405	I A	0~ 6	6	black	7.5 YR 2/1	7.5 YR 3/1	0.96	0.46	52.0	108.2	13	19	50	31	81
		II C_1	6~11	5	dull reddish brown	5 YR 4/4	5 YR 4/3	1.22	0.87	29.1	41.1	9	32	36	32	68
		III C_2	11~35	24	dull brown	7.5 YR 5/4	7.5 YR 5/4	1.11	0.91	18.0	21.9	19	31	20	49	69
		IV C'_1	35~40	5	Brownish black	" 3/2	" 4/2	1.28	1.00	21.6	27.5	5	37	27	36	63
		V C'_2	40~	—	grayish brown	" 4/2	" 5/2	1.12	0.95	15.3	18.0	40	33	17	50	67
2	326	I A	0~10	10	brownish black	7.5 YR 2/2	7.5 YR 3/1	1.08	0.70	34.9	53.6	22	28	37	35	72
		II C	10~32	22	dull reddish brown	5 YR 4/3	5 YR 5/2	1.31	1.13	13.8	16.1	26	39	18	43	61
		III C'_1	32~40	8	dark brownish black	7.5 YR 3/3	7.5 YR 4/2	1.34	1.08	19.6	24.4	12	38	26	36	62
		IV C'_2	40~	—	grayish brown	" 4/2	" 5/1	1.17	0.99	15.9	18.8	52	33	19	48	67
3	423	I A	0~16	16	brownish black	5 YR 3/1	5 YR 3/2	1.05	0.63	40.1	66.9	9	23	42	35	77
		II C_1	16~35	19	brown	7.5 YR 4/4	7.5 YR 5/3	1.22	1.03	15.3	18.0	46	32	19	49	68
		III C_2	35~40	5	grayish brown	" 5/2	" 5/2	1.10	0.88	20.1	25.1	37	31	22	47	69
		IV C'_1	40~46	6	"	5 YR 4/2	5 YR 4/2	1.31	0.90	31.0	45.0	15	32	40	28	68
		V C'_2	46~	—	"	7.5 YR 5/2	7.5 YR 5/2	1.02	0.85	16.4	19.6	71	27	17	56	73

Table 4. Physical and chemical properties of fine soils in natural forests

Plot No.	Location (compartment) No.	Layer	Mechanical analysis (%)				Soil texture	Air-dried moisture (%)	Maximum water holding capacity (water ratio %)	Bulk density	Real specific gravity
			Coarse sand	Fine sand	Silt	Clay					
1	405	A_0	—	—	—	—	—	5.45	—	0.27	1.89
		I A	55	14	9	22	S C L	3.20	139.1	0.74	2.41
		II C_1	74	14	6	6	L S	1.40	41.2	1.23	2.69
		III C_2	93	3	2	2	S	0.36	23.9	1.41	2.93
		IV C_1'	79	10	5	6	L S	1.31	38.6	1.15	2.72
		V C_2'	97	1	1	1	S	0.22	23.5	1.37	2.86
2	326	I A	82	6	5	7	L S	2.90	110.7	0.83	2.51
		II C	95	2	2	1	S	0.25	25.6	1.45	2.89
		III C_1'	88	5	5	2	S	0.74	34.0	1.34	2.84
		IV C_2'	98	1	1	0	S	0.12	24.7	1.46	3.00
3	423	A_0	—	—	—	—	—	6.47	—	0.40	1.96
		I A	71	12	8	9	S L	2.50	63.5	1.01	2.73
		II C_1	93	3	2	2	S	0.50	20.9	1.46	3.19
		III C_2	94	3	1	2	S	0.40	22.8	1.37	2.80
		IV C_1'	84	6	4	6	L S	1.12	34.1	1.21	2.85
		V C_2'	93	3	1	3	S	0.23	21.4	1.50	3.12

pH		Exchange acidity	Loss on ignition	C	N	C-N ratio	Total organic matter	Isolated R_2O_3	CEC	Exchangeable cations (me/100 g)				Degree of base saturation	Absorption coefficient of P_2O_5
H_2O	N-KCl		(%)	(%)	(%)		(%)	(%)	(me/100 g)	Ca	Mg	K	Na	(%)	(mg/100 g)
5.4	4.8	—	—	25.30	1.500	17	43.6	—	58.2	30.93	6.12	2.61	0.30	69	—
5.7	4.8	0.6	16.3	7.11	0.527	13	13.0	0.3	31.1	20.76	3.54	1.29	0.50	84	700
5.7	4.6	1.2	4.0	1.68	0.103	16	3.1	0.5	10.9	2.05	0.27	0.23	0.01	24	480
6.0	5.0	0.3	0.9	0.32	0.022	15	0.6	0.3	3.5	0.53	0.05	0.53	0.18	37	140
6.1	5.0	0.4	3.6	1.59	0.062	26	2.9	0.7	7.7	2.04	0.20	0.69	0.03	38	600
6.6	5.8	0.2	0.4	0.17	0.006	28	0.3	0.1	2.2	0.42	0.05	0.29	0.06	37	90
5.7	5.0	0.3	13.1	6.39	0.388	17	11.7	0.6	25.7	14.74	2.13	0.38	0.12	68	620
6.0	5.1	0.2	0.4	0.14	0.014	10	0.3	0.3	1.9	0.80	0.10	0.04	0.02	51	130
5.9	5.0	0.2	1.8	0.57	0.045	13	1.1	0.7	2.8	1.54	0.17	0.04	0.08	65	300
6.1	5.2	0.1	0.1	0.04	0.037	11	0.1	0.2	0.7	0.21	0.02	0.10	0.01	49	60
5.9	5.5	—	—	23.21	1.121	21	40.0	—	81.2	56.30	9.61	2.72	0.41	85	—
5.6	4.6	0.9	9.4	4.33	0.252	17	7.9	0	12.6	2.38	0.37	0.07	0.07	23	500
6.2	5.2	0.2	1.1	0.59	0.028	21	1.1	0.4	2.6	0.48	0.06	0.03	0.03	23	190
6.3	5.4	0.1	0.7	0.18	0.014	13	0.3	0.4	2.1	0.57	0.06	0.03	0.03	33	170
6.0	5.0	0.3	3.1	1.14	0.071	16	2.1	0.9	6.1	1.07	0.09	0.03	0.05	20	380
6.4	5.8	0.2	0.5	0.17	0.008	21	0.3	0.5	1.0	0.30	0.03	0.07	0.07	47	80

Table 5. Moisture contents at various pF values of fine soils in natural forests (water ratio %)

No.	Location (compartment)	Layer	pF 0	pF 1.6	pF 2.7	pF 3.1	pF 3.9	pF 4.2	pF 5.7	Available moisture (points)
1	405	I A	139.1	62.7	45.4	38.3	28.9	25.2	3.3	37.5
		II C_1	42.2	20.3	10.7	8.3	5.6	4.5	1.4	15.8
		III C_2	23.9	5.7	4.3	3.8	2.8	1.8	0.4	3.9
		IV C_1'	38.6	15.8	10.0	7.6	4.6	3.6	1.3	12.2
		V C_2'	23.5	5.2	3.9	3.1	1.9	1.2	0.2	4.0
2	326	I A	110.7	38.3	30.5	26.8	19.7	16.7	3.0	21.6
		II C	25.6	7.7	5.0	4.1	2.4	1.5	0.3	6.2
		III C_1'	34.0	11.8	7.6	6.2	3.2	2.6	0.7	9.2
		IV C_2'	24.7	4.6	3.1	2.6	1.5	1.0	0.1	3.6
3	423	I A	63.5	27.5	17.8	15.2	10.5	8.7	2.6	18.8
		II C_1	20.9	5.2	3.8	3.1	2.0	1.7	0.5	3.5
		III C_2	22.8	5.6	4.2	3.8	2.5	2.0	0.4	3.6
		IV C_1'	34.1	13.7	9.3	7.7	4.6	3.7	1.1	10.0
		IV C_2'	21.4	4.6	3.2	2.6	1.6	1.0	0.2	3.6

Table 6. Mineral components of A layer matters and IA layer soils in natural forests

Plot No.	Location (compartment) No.	Layer	Thickness (cm)	Apparent specific gravity (dried)	Organic matter (%)	N (%)	Mineral matter (%)	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	K_2O	Na_2O	P_2O_5	Total
								Components as oxides (%)								
1	405	A_0	3	0.06	43.6	1.50	56.4	34.0	6.8	6.9	1.8	3.1	0.3	0.8	0.14	53.84
		I A	6	0.46	13.0	0.53	87.0	51.8	11.3	11.2	1.7	3.6	0.3	1.0	0.10	81.00
3	423	A_0	3	0.08	40.0	1.10	60.0	36.1	7.4	6.9	1.8	4.0	0.3	0.6	0.15	57.25
		I A	16	0.63	7.9	0.25	92.1	54.9	12.6	12.3	1.7	3.7	0.3	1.1	0.06	86.66

contents as well as CEC and the values of exchageable cations are low with exception of Ao and IA. The phosphoric acid absorption is also extremely low for all the soil samples, though the volcanic ash soils or Andosols are said to be generally high owing to the active aluminum contained.

As an important factor of the physical properties, there is a relationship between the pF values and the moisture in the soils, which is shown in Table 5. The water retention ability of the soils at the pF value of 1.6 (corresponding to field capacity), 2.7 (moisture equivalent), 3.1 (*lento* capillary point), 3.9 (temporary wilting point), and 4.2 (permanent wilting point) are all low, so that the available water calculated by the difference between the water ratios at 1.6 and 4.2 of the pF also low, except IA. Table 2 reveals that the moistures in the fresh soils correspond to the content in less than 1.6 of the pF. Therefore, it would be said that the soils in the natural forests are in an excessive moist state, although the percentage of water is low. From these results, the soils are concluded to be infertile but excellent in water and air permeability necessary for the roots of trees.

The chemical composition of inorganic materials as oxide in Ao and IA layer is shown in Table 6. Ao-matters contain the mineral components as considerably high as 56 to 60 percent. Naturally the content of SiO_2 is the highest. Those of Al_2O_3 and Fe_2O_3 are similar to each other and followed by the content of CaO, MgO, Na_2O, K_2O and P_2O_5 in a row. The contents of IA layer is very similar to those of Ao layer.

2. Todomatsu-Fir Plantation Soils

Table 7 gives the outlines of Todomatsu-fir plantation. Among the relatively new plantations carried out in 1963, the growths at plot No. 4 are superior to plot No. 5. The trees of the former plantation appear to suffer the less frost and saline wind damages, as the stand in compartment 203 is located on the northern slope farthest from the coast. Plot No. 6 in the forest planted in 1937 showed the mean tree has the height of 10.5 m and 14.4 cm in diameter at breast height, while the mean tree of plot No. 7 in the Shiraoi national forest planted only by 2 years earlier showed a considerable growth as seen in the height of 17.9 m and the diameter of 21.3 cm. The growing stock in the national forest was estimated at 394 m^3 a hectare, more than three times of the stock of the Tomakomai man-made forest. The difference of the growth between the two seems to be mainly attributed to the fertility of the soils.

Soil properties under natural condition are given in Table 8. The Tomakomai soils consist all of C horizons unweathered except the first thin layer of A horizon. On the contrary, the Shiraoi soils are alluvial soils consisting of volcanic ashes and are fully differentiated in A, B and C horizons. Within the profiles observed with naked eye, the soils at plot No. 4 are divided into 6 layers, in which the upper 4 layers appear to correspond to Ta-a formation being some 70 cm thick and the rests probably belong to Ta-b accumulated by the eruption in 1667 A. D. The second layer with a thickness of 18 cm contained a hard pan as thin as 1 cm including richly fine sand and silt, impossible for the investigation in the field.

Table 7. Descriptions of

Plot No.	Location (compartment)	Year of plantation	Area of plantation (ha)	Slope and direction	Planted numbers per ha	Tending treatment	
						Weeding	Improvement cutting
4	203	1963	1.00 (patch)	NW 15°	4,300	8	1
5	409	1963	6.50	flat	3,150	6	1
6	138	1937	2.19	〃	3,000	4	4
7	Shiraoi national forest	1934	7.59	〃	3,000	4	4

Table 8. Physical properties of Todomatsu-fir

Plot No.	Location (compartment)	Layer	Depth (cm)	Thickness (cm)	Color		
					Description of fresh soil with naked eye	Fresh soil by Munsell	Dried soil by Munsell
4	203	I A	0~ 8	8	brownish black	7.5 YR 2/2	7.5 YR 3/1
		II C_1	8~26	18	brown	〃 4/4	〃 5/4
		III C_2	26~45	19	dull brown	〃 5/3	〃 6/3
		IV C_3	45~71	26	grayish brown	〃 5/1	〃 6/1
		V C_1'	71~77	6	brownish black	〃 2/2	〃 3/2
		VI C_2'	77~	—	brown	〃 4/3	〃 5/2
5	409	I A	0~12	12	brownish black	7.5 YR 2/2	7.5 YR 3/2
		II C_1	12~23	11	bright brown	〃 5/6	〃 5/4
		III C_2	23~46	23	dull brown	〃 5/3	〃 5/2
		IV C_1'	46~54	8	grayish brown	5 YR 4/2	〃 4/2
		V C_2'	54	—	〃	〃 5/2	〃 4/1
6	138	I A	0~ 7	7	brownish black	5 YR 2/2	5 YR 3/1
		II C	7~20	13	brown	7.5 YR 4/4	7.5 YR 3/4
		III C_1'	20~29	9	dark brown	〃 3/4	〃 4/2
		IV C_2'	29~	—	grayish brown	〃 4/2	〃 4/1
7	Shiraoi national forest	I A	0~ 8	8	very dark brown	7.5 YR 2/3	7.5 YR 3/2
		II B_1	8~14	6	dullbrown	〃 5/4	〃 5/3
		III B_2	14~44	30	brown	〃 4/4	〃 4/3
		IV C	44~	—	brown	〃 4/6	〃 5/4

Todomatsu-fir plantation sites

Date of inventory	Survived numbers per ha	Result of growth				
		Mean tree				Growing stock
		Height (m)	Diameter at breast height (cm)	Coefficient of variation in diameter (%)		(m³/ha)
Oct. 1972	4,090	2.1	2.0	—		—
"	2,600	1.5	2.0	—		—
"	1,380	10.5 / (5～16)	14.4 / (8～24)	23.9		116
Aug. 1972	1,230	17.9 / (5～24)	21.3 / (8～38)	32.0		394

plantation soils under natural condition

Apparent specific gravity		Moisture content based on		Gravel	Distribution of three phases in soil (Vol. %)			Porosity
Fresh soil	Dried soil	Fresh soil (%)	Dried soil (%)	(%)	Soild	Liquid	Gas	(Vol. %)
0.96	0.59	38.4	62.4	5	22	37	41	78
1.11	0.96	13.3	15.4	4	35	15	50	65
1.01	0.78	22.4	28.9	46	28	23	49	72
1.12	0.86	22.9	29.7	15	30	26	44	70
1.24	0.81	35.1	54.1	29	30	44	26	70
1.03	0.85	17.9	21.9	82	31	19	50	69
1.18	0.84	28.4	39.7	4	33	34	33	67
1.02	0.80	21.3	27.1	61	25	22	53	75
1.18	0.99	16.1	19.2	22	35	19	46	65
1.05	0.76	27.1	37.2	19	27	28	45	73
1.09	0.91	16.8	20.2	67	31	18	51	69
1.09	0.70	35.7	55.6	38	28	39	33	72
1.30	1.09	16.2	19.3	26	36	21	43	64
1.43	1.22	14.6	17.1	18	44	21	35	56
1.22	1.05	14.0	16.2	48	35	17	48	65
0.70	0.40	43.4	76.8	15	16	31	53	84
0.97	0.62	36.2	56.7	6	23	35	42	77
0.72	0.38	46.9	88.3	11	14	34	52	86
0.68	0.42	37.6	60.2	13	17	25	58	83

Table 9. Physical and chemical properties of fine soils in Todomatsu-fir plantations

Plot No.	Location (compartment) No.	Layer	Mechanical analysis (%)				Soil texture	Air-dried moisture (%)	Maximum water holding capacity (water ratio %)	Bulk density	Real specific gravity	pH	
			Coarse sand	Fine sand	Silt	Clay						H_2O	N-KCl
4	203	A_0	—	—	—	—	—	6.12	—	0.08	2.00	5.9	5.3
		I A	76	8	0	16	S C L	2.57	60.3	1.00	2.63	5.9	4.9
		II C_{1-1}	96	2	0	2	S	0.27	34.3	1.26	2.75	6.1	5.2
		II' C_{1-2}	62	18	17	3	S L	1.08	34.6	1.36	2.56	5.9	4.9
		III C_2	91	4	1	4	S	0.22	25.5	1.42	2.79	6.2	5.6
		IV C_3	91	7	0	2	S	0.16	29.4	1.29	2.87	6.3	5.6
		V C_1'	76	11	6	7	L S	1.77	45.9	1.14	2.67	6.0	5.0
		VI C_2'	89	5	4	2	S	0.57	25.0	1.46	2.74	6.2	5.5
5	409	A_0	—	—	—	—	—	5.42	—	0.10	2.15	6.0	5.4
		I A	80	9	6	5	L S	1.45	35.9	1.30	2.70	5.7	4.8
		II C_1	93	3	3	1	S	0.47	22.2	1.48	2.98	6.0	5.1
		III C_2	97	1	1	1	S	0.26	22.1	1.40	2.82	6.1	5.4
		IV C_1'	93	2	2	3	S	0.82	29.3	1.25	2.79	6.1	5.1
		V C_2'	96	2	1	1	S	0.16	19.7	1.48	2.81	6.4	6.0
6	138	A_0	—	—	—	—	—	7.18	—	0.10	1.64	3.7	3.4
		I A	86	4	3	7	L S	3.59	119.7	0.75	2.51	5.4	4.7
		II C	92	4	1	3	S	0.59	23.3	1.49	3.00	6.1	5.1
		III C_1'	93	3	2	2	S	0.69	24.9	1.45	2.74	6.1	5.2
		IV C_2'	96	2	1	1	S	0.21	23.0	1.48	3.01	6.3	5.9
7	Shiraoi national forest	I A	22	35	26	17	C L	6.53	109.0	0.69	2.50	5.1	4.3
		II B_1	19	40	32	9	L	4.04	81.0	0.86	2.70	5.3	4.6
		III B_2	25	45	21	9	S L	4.97	80.1	0.89	2.71	5.5	4.5
		IV C	78	14	1	7	L S	3.80	73.6	0.76	2.54	5.6	5.0

Exchange acidity	Loss on ignition (%)	C (%)	N (%)	C-N ratio	Total organic matter (%)	Isolated R_2O_3 (%)	CEC (me/100 g)	Exchangeable cations (me/100 g)				Degree of base saturation (%)	Absorption coefficient of P_2O_5 (mg/100 g)
								Ca	Mg	K	Na		
—	—	22.31	1.110	20	38.4	—	72.1	47.30	5.31	2.60	0.22	77	—
0.5	7.7	3.44	0.184	19	6.3	0.6	11.0	4.64	0.65	0.83	0.04	56	510
0.3	0.9	0.57	0.036	16	0.9	0.2	3.4	0.81	0.10	0.14	0.02	32	170
—	1.8	0.60	0.032	19	1.1	0.4	6.6	—	—	—	—	—	—
0.3	0.7	0.14	0.014	10	0.3	0.3	3.1	0.48	0.05	0.34	0.01	28	170
0.2	0.6	0.12	0.006	20	0.2	0.1	2.9	0.35	0.03	0.26	0.01	22	110
0.4	4.8	2.11	0.137	15	3.9	0.0	8.2	2.03	0.27	0.24	0.05	32	540
0.5	0.5	0.12	0.006	20	0.2	0.4	1.1	0.13	0.10	0.14	0.04	37	420
—	—	18.62	1.020	19	32.1	—	54.3	27.41	5.80	2.81	0.31	67	—
0.7	10.5	5.36	0.294	18	9.8	0.5	9.0	1.93	0.23	0.07	0.11	26	450
0.3	0.7	0.24	0.023	10	0.4	0.4	2.7	0.37	0.05	0.04	0.05	19	80
0.2	0.5	0.23	0.023	10	0.4	0.4	1.4	0.16	0.02	0.01	0.06	18	50
0.2	2.2	0.68	0.046	15	1.3	1.2	5.9	1.31	0.10	0.04	0.06	26	260
0.2	0.3	0.17	0.009	19	0.3	0.4	0.7	0.16	0.02	0.03	0.04	36	70
—	—	38.30	1.721	22	66.0	—	63.6	15.80	3.91	1.20	0.61	34	—
1.4	16.1	7.42	0.354	21	13.6	0.4	30.9	13.61	1.89	0.27	0.26	52	570
0.3	1.0	0.59	0.026	23	1.1	0.3	2.1	0.58	0.09	0.04	0.03	35	180
0.2	1.0	0.45	0.028	16	0.8	0.5	2.2	0.50	0.09	0.05	0.04	31	80
0.2	0.3	0.12	0.005	24	0.2	0.2	0.8	0.17	0.03	0.07	0.01	35	70
5.3	14.2	6.03	0.456	13	11.0	0	18.1	1.81	0.38	0.33	0.14	15	1030
2.2	6.9	2.60	0.210	12	4.8	1.2	8.8	0.64	0.11	0.13	0.10	11	920
2.2	7.4	3.39	0.203	17	6.2	2.5	9.6	1.14	0.15	0.13	0.26	18	1080
0.4	4.3	1.01	0.055	18	1.8	1.6	4.4	0.72	0.07	0.10	0.10	22	820

This pan making no appearance in any other plots, was analyzed separately as II' layer in the laboratory. The sixth layer was mainly formed from gravels. The soils at plot No. 5 in the compartment 409 situated on the inner flat land in the Experiment Forest were divided into 5 layers, in which the upper 3 layers appear to belong to Ta-a having a thickness of 46 cm. The second and fifth layers are mainly composed of gravels amounting to more than 60 percent. Plot No. 6 divided into 4 layers in the 1-m depth had only a 20 cm thick formation belonging to Ta-a. Meanwhile, the Shiraoi alluvial forest soils consisting probably of volcanic ashes of Us-c formation erupted from Mt. Usu[2] are soft and have a low apparent specific gravity and a remarkably low percentage of solid in the three-phase distribution, compared with the Tomakomai soils.

The results of the analyses of fine soils including Ao in the Tomakomai plantations are shown in Table 9. Mechanical composition of the Tomakomai soils reveals that every layer consists of sand excluding that of IA layer, while the soil class of the Shiraoi soils belongs to loamy textures. The size-distribution in II' layer with a 1-cm thickness at plot No. 4 showed to be sandy loam. Air-dried moisture and maximum water holding capacity from the Tomakomai subsoils are extremely low, similar to those of the natural forests. Contrary to them, the Shiraoi soils are possessed of the relatively high moisture and the high capacity in all layers. Concerning the chemical properties, any subsoils derived from Ta-a and Ta-b deposits are nearly neutral in pH and low in the values of Y_1, carbon and nitrogen, as well as low in CEC and the absorption of phosphoric acid, while the soils of IA and the humus matters of Ao show the properties reversed to the subsoils. The CEC of Ao is very high and the exchageable base consists mostly of calcium, Though the Shiraoi soils are low in pH, especially potential pH with N-KCl solution, the properties can be said to be generally good for the growth of trees.

As one of the important physical properties, the moisture content at various pF was examined using fine soils by a centrifugal method, as shown in Table 10, including the contents at maximum water holding capacity (pF 0) and at air-dry (pF 5.7). Since the soils of the Tomakomai IA contained humus matters, each moisture is comparatively high, but the subsoils show the extremely low water retention and accordingly are as low as several percent in the available water. On the contrary the Shiraoi soils have high water retention at any pF and are rich in the available moisture essential for the growth.

Inorganic chemical components determined using an atomic absorption spectrophotometer after digesting with HF and *aqua regia* are given in Table 11. The content of SiO_2 is maximum. Those of Al_2O_3 and Fe_2O_3 are similar to each other, and followed by CaO. That of P_2O_5 in A_0 is higher than in IA.

Table 10. Moisture contents at various pF values of fine soils in Todomatsu-fir plantations (water ratio %)

No.	Location (compartment)	Layer	pF							Available moisture (points)
			0	1.6	2.7	3.1	3.9	4.2	5.7	
4	203	I A	60.3	26.7	16.2	12.7	8.1	6.7	2.7	20.0
		II C_1	34.3	5.6	3.8	3.0	1.8	1.1	0.3	4.5
		III C_2	25.5	5.8	4.2	3.2	1.7	1.4	0.2	4.4
		IV C_3	29.4	8.5	5.9	4.9	3.0	2.0	0.2	6.5
		V C'_1	45.9	15.3	10.2	8.3	5.6	4.7	1.8	10.6
		VI C'_2	25.0	6.6	4.6	3.7	2.0	1.3	0.6	5.3
5	409	I A	35.9	15.8	10.8	8.8	5.8	5.2	1.5	10.6
		II C_1	22.2	4.8	3.5	2.9	1.5	1.0	0.5	3.8
		III C_2	22.1	4.4	3.2	2.8	1.9	1.6	0.3	2.8
		IV C'_1	29.3	10.3	6.9	5.7	2.8	2.2	0.8	8.1
		V C'_2	19.7	4.0	2.7	2.2	1.3	0.9	0.2	3.1
6	138	I A	119.7	55.4	38.9	33.4	22.1	19.1	3.7	36.3
		II C	23.3	5.9	4.2	3.8	2.8	2.2	0.6	3.7
		III C'_1	24.9	6.2	4.4	3.8	2.3	1.9	0.7	4.3
		IV C'_2	23.0	3.6	2.3	2.0	1.3	0.8	0.2	2.8
7	Shiraoi national forest	I A	109.0	82.3	49.5	41.6	25.6	21.4	6.9	60.9
		II B_1	81.0	62.2	34.3	28.2	15.4	11.9	4.2	50.3
		III B_2	80.1	56.0	30.7	22.4	14.7	12.1	5.3	43.9
		IV C	73.6	40.8	26.2	20.6	11.8	9.3	3.9	31.5

3. Stem Analysis of Todomatsu-Fir Trees

Two typical Todomatsu-fir trees felled in the plantations at plot No. 6 of the Tomakomai forest and No. 7 of the Shiraoi national forest were provided for the stem analysis. The former was 42 years old, 11.4 m high and 16 cm in diameter at breast height, while the latter was 44 years old, 17.50 m high and 23 cm. The summaries of growths and increments are given in Tables 12 and 13 as well as Figures 2 and 3. The age of the two trees is not so different but the difference in the growths is remarkable. Examining with a stand yield table of the fir plantation, the Tomakomai and Shiraoi plantations belong to the worst and second site class in Hokkaido, respectively.[5] The growth rate of the Tomakomai plantation stand rather exceeding those of the Shiraoi stand for some 10 years after planting, drop rapidly down thereafter. The reason seems to be based on the differences of the soil properties.

Table 11. Mineral componotns of A layer matters

Plot No.	Location (compartment) No.	Layer	Thickness (cm)	Apparent specific gravity (dried)	Organic matter (%)	N (%)	Mineral matter (%)
4	203	A_0	4.0	0.08	38.4	1.1	61.6
5	409	A_0	2.0	0.10	32.1	1.0	67.9
		I A	12.0	0.84	9.8	0.3	90.2
6	138	A_0	4.0	0.10	66.0	1.7	34.0
		I A	7.0	0.70	13.6	0.4	86.4

Table 12. Descriptions of growths of a typical Todomatsu-fir

Age class	Height					Diameter at breast height				
	growth (m)	periodic increment (m)	annual increment (m)	mean increment (m)	growth rate (%)	growth (cm)	periodic increment (cm)	annual increment (cm)	mean increment (cm)	growth rate (%)
5	0.30	0.30	0.06	0.06	—	0.00	0.00	0.00	0.00	—
10	1.70	1.40	0.28	0.17	41.47	0.20	0.20	0.04	0.02	—
15	2.97	1.27	0.25	0.20	11.81	2.71	2.51	0.50	0.18	67.05
20	4.97	2.00	0.40	0.25	10.85	5.73	3.02	0.60	0.29	18.72
25	6.97	2.00	0.40	0.29	7.00	8.20	2.47	0.49	0.33	7.43
30	9.30	2.33	0.47	0.31	5.94	9.93	1.73	0.35	0.33	3.90
35	10.10	0.80	0.16	0.29	1.66	11.65	1.72	0.34	0.33	3.25
40	10.90	0.80	0.16	0.27	1.54	12.64	0.99	0.20	0.32	1.65
42	11.40	0.50	0.25	0.27	2.13	12.83	0.18	0.09	0.31	0.75

Table 13. Descriptions of growths of a typical Todomatsu-

Age class	Height					Diameter at breast height				
	growth (m)	periodic increment (m)	annual increment (m)	mean increment (m)	growth rate (%)	growth (cm)	periodic increment (cm)	annual increment (cm)	mean increment (cm)	growth rate (%)
5	0.30	0.30	0.06	0.06	—	0.00	0.00	0.00	0.00	—
10	1.80	1.50	0.30	0.18	43.10	0.43	0.43	0.09	0.04	—
15	4.10	2.30	0.46	0.27	17.90	3.86	3.43	0.69	0.26	55.10
20	6.10	2.00	0.40	0.31	8.27	7.31	3.45	0.69	0.37	13.62
25	8.30	2.20	0.44	0.33	6.35	10.55	3.24	0.65	0.42	7.61
30	11.30	3.00	0.60	0.38	6.37	14.84	4.29	0.86	0.50	7.06
35	14.30	3.00	0.60	0.41	4.82	18.01	3.17	0.63	0.52	3.95
40	16.80	2.50	0.50	0.42	3.28	20.01	2.00	0.40	0.50	2.13
44	17.50	0.70	0.18	0.40	1.03	20.87	0.86	0.22	0.47	1.05

and IA layer soils in Todomatsu-fir plantations

Components as oxides (%)								
SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	K_2O	Na_2O	P_2O_5	Total
37.4	7.8	5.7	2.0	3.0	0.5	0.9	0.22	57.52
41.3	9.1	8.7	2.1	3.3	0.5	0.6	0.11	65.71
53.9	12.4	12.2	2.0	3.9	0.3	1.0	0.06	85.76
20.1	3.9	4.3	1.1	1.9	0.4	0.6	0.16	32.46
51.4	11.2	10.6	2.4	4.0	0.4	0.9	0.09	80.99

planted at plot No. 6 in Tomakomai Exp. Forest

Basal area at breast height					Volume				
growth (m^2)	periodic increment (m^2)	annual increment (m^2)	mean increment (m^2)	growth rate (%)	growth (m^3)	periodic increment (m^3)	annual increment (m^3)	mean increment (m^3)	growth rate (%)
0.0000	0.0000	0.0000	0.0000	—	0.0000	0.0000	0.0000	0.0000	—
0.0000	0.0000	0.0000	0.0000	—	0.0001	0.0001	0.0001	0.0000	—
0.0006	0.0006	0.0001	0.0000	—	0.0021	0.0020	0.0005	0.0001	83.84
0.0026	0.0020	0.0004	0.0001	34.08	0.0071	0.0050	0.0010	0.0004	27.59
0.0053	0.0027	0.0005	0.0002	15.31	0.0186	0.0115	0.0023	0.0007	21.24
0.0077	0.0024	0.0005	0.0003	7.76	0.0331	0.0145	0.0029	0.0011	12.22
0.0107	0.0030	0.0006	0.0003	6.80	0.0541	0.0210	0.0042	0.0015	10.33
0.0125	0.0018	0.0004	0.0003	3.16	0.0718	0.0177	0.0035	0.0018	5.82
0.0129	0.0004	0.0002	0.0003	1.59	0.0748	0.0030	0.0015	0.0018	2.07

fir planted at plot No. 7 in Shiraoi national forest

Basal area at breast height					Volume				
growth (m^2)	periodic increment (m^2)	annual increment (m^2)	mean increment (m^2)	growth rate (%)	growth (m^3)	periodic increment (m^3)	annual increment (m^{ε})	mean increment (m^2)	growth rate (%)
0.0000	0.0000	0.0000	0.0000	—	0.0000	0.0000	0.0000	0.0000	—
0.0000	0.0000	0.0000	0.0000	—	0.0003	0.0003	0.0001	0.0000	—
0.0012	0.0012	0.0002	0.0001	—	0.0026	0.0023	0.0005	0.0002	54,02
0.0042	0.0030	0.0006	0.0002	28.47	0.0122	0.0096	0.0019	0.0006	36.23
0.0087	0.0045	0.0009	0.0003	15.68	0.0364	0.0242	0.0048	0.0023	24.44
0.0173	0.0086	0.0017	0.0006	14.74	0.0900	0.0536	0.0107	0.0030	19.85
0.0255	0.0082	0.0016	0.0007	8.07	0.1688	0.0788	0.0158	0.0048	13.40
0.0314	0.0059	0.0012	0.0008	4.25	0.2486	0.0798	0.0160	0.0062	8.05
0.0342	0.0028	0.0007	0.0008	2.10	0.2933	0.0447	0.0112	0.0067	4.22

Table 14. Proximate chemical composition of various parts in Todomatsu-firs (%)

Plot No.	Location (compartment)	Sample	Ash	Solubitity in				Total pentosan	Methyl pentosan	Holo-cellulose	Alpha cellulose	Lignin	Total N
				Alcohol benzene	Cold water	Hot water	1%-NaOH						
6	138	Bark	2.89	24.7	11.3	23.5	58.1	11.2	2.2	42.2	25.6	23.3	0.43
		Lower part sapwood	0.15	3.2	2.5	3.7	14.4	11.8	2.8	63.8	40.1	29.7	0.11
		Lower part heartwood	0.11	4.5	3.1	4.1	16.2	11.7	3.3	63.3	38.3	31.7	0.04
		Middle part wood	0.17	2.7	2.4	3.3	13.4	10.5	2.3	64.0	38.2	29.0	0.03
		Top part wood	0.28	2.1	2.7	3.2	12.9	10.3	2.4	65.2	39.0	29.5	0.10
		Branch	0.51	5.4	3.3	5.0	14.4	10.2	2.5	63.3	38.5	32.1	0.08
		Needle leaves	6.09	29.5	26.8	33.7	69.7	9.7	3.1	27.4	18.6	30.2	1.66
7	Shiraoi national forest	Bark	3.44	27.9	17.4	26.2	76.9	8.6	3.6	33.8	21.5	28.7	0.46
		Lower part sapwood	0.21	2.2	2.2	2.3	18.2	9.3	1.2	65.5	40.6	28.7	0.10
		Lower part heartwood	0.35	5.4	3.6	5.0	22.2	12.3	4.5	64.5	39.2	27.3	0.07
		Middle partwood	0.20	3.1	2.5	3.4	18.3	12.0	3.3	61.6	37.3	29.5	0.07
		Middle part wood	0.38	3.0	3.2	3.8	20.3	12.5	3.1	58.4	35.2	30.4	0.10
		Branch	0.67	5.0	6.0	6.2	26.1	11.3	0.8	54.4	33.1	33.6	0.17
		Needle leaves	6.20	31.5	25.1	30.0	64.2	8.4	2.3	30.0	20.9	27.6	2.17

Table 15. Mineral composition of leaves of main trees, *Sasa* and *Sasamorpha* species (%)

Sample		Location (compartment)	N	Ash	Components as oxides								
					SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	K_2O	Na_2O	P_2O_5	Total
Picea jezoensis	I	405	1.24	5.96	2.29	0.08	0.17	0.19	1.46	1.76	0.05	0.19	6.19
〃	II	405	1.16	6.87	2.75	0.11	0.14	0.26	1.32	1.55	0.04	0.30	6.17
Abies sachalinensis	I	409	1.90	4.86	0.92	0.12	0.07	0.19	1.74	1.20	0.05	0.28	4.57
〃	II	409	1.20	4.39	0.92	0.08	0.03	0.18	1.56	1.15	0.02	0.22	4.16
〃	III	138	1.66	6.09	1.41	0.18	0.05	0.20	1.91	1.68	0.03	0.23	5.69
Quercus mongolica var. *grosseserrata*	I	405	2.71	7.92	2.98	0.26	0.19	0.40	1.83	1.26	0.13	0.40	7.45
〃	II	423	3.04	7.94	2.79	0.32	0.18	0.33	2.10	1.20	0.26	0.31	7.49
Tilia japonica	I	326	3.25	6.69	0.76	0.07	0.03	0.35	2.42	2.15	0.05	0.51	6.34
〃	II	405	3.41	8.63	1.25	0.09	0.06	0.48	2.98	2.60	0.07	0.49	8.02
Kalopanax pictus		405	3.09	11.22	1.76	0.11	0.31	0.43	4.41	2.85	0.10	0.49	10.46
Sasa senanensis		404	2.11	10.80	8.48	0.02	0.29	0.15	0.30	0.94	0.02	0.09	10.29
Sasa apoiensis		308	1.70	16.99	12.68	0.14	0.22	0.27	0.58	1.84	0.05	0.18	15.96
Sasamorpha borealis		423	1.93	11.61	8.34	0.09	0.15	0.19	0.68	1.32	0.04	0.18	10.99

Table 16. Properties of buried soils

Layer	Depth (cm)	Thickness (cm)	Color		
			Description of fresh soil with naked eye	Fresh soil by Munsell	Dried soil by Munsell
I A	0 ～ 6.5	6.5	brownish black	7.5 YR 2/2	5 YR 3/2
II C_1	6.5～ 14.5	8	brown	〃 4/4	7.5 YR 4/3
III C_2	14.5～ 27.5	13	〃	〃 4/4	〃 4/2
IV C'_1	27.5～ 35.5	8	dark reddish brown	5 YR 3/3	〃 4/2
V C'_2	35.5～ 85.5	50	grayish brown	7.5 YR 4/2	〃 5/2
VI C'_3	85.5～110.5	25	〃	〃 4/2	〃 7/2
VII C'_4	110.5～115.5	5	brown	〃 4/3	〃 6/3
VIII C'_5	115.5～135.5	20	grayish brown	5 YR 4/2	5 YR 6/2
IX C'_6	135.5～210.5	75	dull brown	7.5 YR 5/3	7.5 YR 6/3
X C'_7	210.5～275.5	65	〃	〃 5/3	〃 7/2
XI A''	275.5～300.5	25	black	5 YR 1.7/1	5 YR 2/2
XII B''	300.5～315.5	15	brown	7.5 YR 4/6	7.5 YR 5/3
XIII C''	315.5～368.5	53	bright brown	〃 5/6	〃 5/4
XIV A'''	368.5～405.5	37	black	〃 1.7/1	〃 2/1
XV B'''_1	405.5～416.5	11	dark brown	10 YR 3/4	10 YR 5/3
XVI B'''_2	416.5～441.5	25	brown	7.5 YR 4/6	7.5 YR 5/4
XVII B'''_3	441.5～520.5	79	orange	5 YR 6/8	5 YR 6/6
XVIII B'''_4	520.5～532.5	12	brown	7.5 YR 4/6	7.5 YR 6/6
XIX A''''	532.5～545.5	13	brownish brown	5 YR 2/1	5 YR 3/1
XX B''''	545.5～	—	brown	10 YR 4/6	10 YR 6/4

Table 17. Properties of buried soils

Layer	Depth (cm)	Thickness (cm)	Color		
			Description of fresh soil with naked eye	Fresh soil by Munsell	Dried soil by Munsell
I A	0～ 9	9	very dark brown	7.5 YR 2/3	7.5 YR 3/2
II C_1	9～ 25	16	brown	〃 4/4	〃 5/3
III C_2	25～ 36	11	dark brown	〃 3/4	〃 5/3
IV C_3	36～ 65	29	grayish brown	〃 4/2	〃 5/2
V C'_1	65～ 75	10	brown	〃 4/3	〃 6/3
VI C'_2	75～ 94	19	grayish brown	〃 4/2	〃 6/3
VII C'_3	94～152	58	dull brown	〃 5/3	〃 5/2
VIII C'_4	152～156	4	brown	〃 4/6	〃 5/4
IX C'_5	156～328	172	grayish brown	〃 5/2	〃 6/2
X A''	328～349	21	black	〃 2/1	〃 3/1
XI C''	349～375	26	very dark brown	〃 2/3	〃 4/2
XII A'''	375～417	42	black	〃 1.7/1	〃 2/1
XIII B'''	417～467	50	bright brown	5 YR 4/8	5 YR 5/6
XIV A''''	467～503	36	brownish black	7.5 YR 2/2	7.5 YR 3/1
XV B''''_1	503～516	13	brown	〃 4/6	〃 5/4
XVI B''''_2	516～544	28	〃	〃 4/6	〃 6/4
XVII B''''_3	544～	—	bright brown	〃 5/6	〃 6/4

at plot No. 8 under natural condition

Apparent specific gravity		Moisture content based on		Gravel	Distribution of three phases in soil (Vol. %)			Porosity
Fresh soil	Dried soil	Fresh soil (%)	Dried soil (%)	(%)	Solid	Liquid	Gas	(Vol. %)
0.89	0.59	33.9	51.4	18	22	30	48	78
1.09	0.80	26.6	36.3	30	27	29	44	73
1.19	0.99	16.5	19.8	36	33	20	47	67
1.22	0.95	21.9	28.1	18	33	27	40	67
1.09	0.93	14.5	16.9	44	32	16	52	68
0.92	0.67	27.0	37.0	78	23	25	52	77
1.17	0.98	16.4	19.6	65	33	19	48	67
0.98	0.77	21.8	28.0	70	27	21	52	73
1.01	0.78	23.1	30.0	65	26	23	51	74
0.78	0.52	33.4	50.2	83	17	26	57	83
1.25	0.58	53.4	114.4	7	24	67	9	76
1.23	0.87	29.4	41.6	13	33	36	31	67
1.08	0.83	22.9	29.7	53	27	25	48	73
0.98	0.41	58.0	137.9	12	17	57	26	83
1.16	0.85	26.6	36.2	26	31	31	38	69
1.25	0.98	21.5	27.4	34	36	27	37	64
0.81	0.27	66.6	199.6	0	10	54	36	90
0.85	0.45	46.6	87.2	0	17	39	44	83
1.33	0.66	50.2	100.8	0	26	66	8	74
1.20	0.78	35.3	54.5	0	29	42	29	71

at plot No. 9 under natural condition

Apparent specific gravity		Moisture content based on		Gravel	Distribution of three phases in soil (Vol. %)			Porosity
Fresh soil	Dried soil	Fresh soil (%)	Dried soil (%)	(%)	Solid	Liquid	Gas	(Vol. %)
1.08	0.77	28.6	40.1	15	28	31	41	72
1.24	1.04	15.7	18.6	24	35	19	46	65
1.29	1.11	13.7	15.8	14	39	17	44	61
1.23	1.08	11.8	13.4	43	36	15	49	64
1.34	1.12	16.5	19.7	48	41	22	37	59
1.21	0.99	17.9	21.8	31	33	22	45	67
1.05	0.79	24.9	33.1	56	25	26	49	75
1.16	0.96	17.5	21.3	40	33	20	47	67
0.86	0.61	29.2	41.3	63	20	25	55	80
1.24	0.76	38.7	63.1	16	28	48	24	72
1.10	0.87	21.3	27.1	38	29	23	48	71
1.02	0.46	54.5	119.7	0	20	55	25	80
0.96	0.43	55.5	124.5	7	19	53	28	81
1.17	0.54	53.2	113.7	0	22	62	16	78
1.27	0.71	43.7	77.7	5	26	56	18	74
1.02	0.61	40.7	68.6	3	22	42	36	78
1.24	0.68	45.0	81.8	0	25	56	19	75

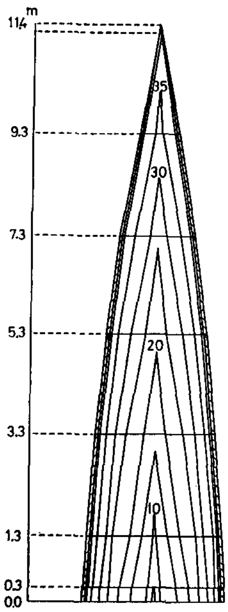

Fig. 2. Stem analysis of a typical Todomatsu-fir planted in Tomakomai Exp. Forest.

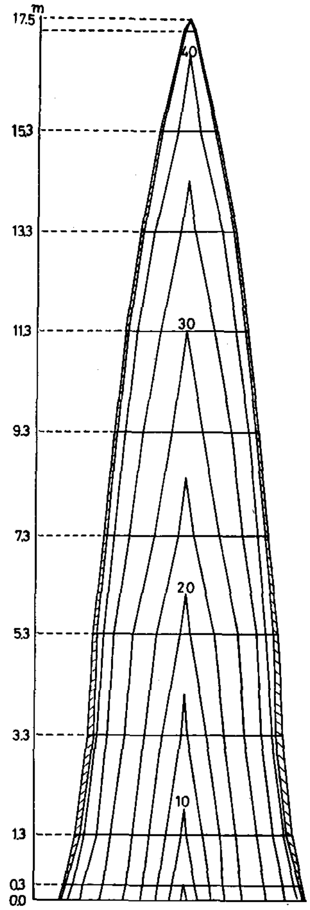

Fig. 3. Stem analysis of a typical Todomatsu-fir planted in Shiraoi national forest.

4. Chemical Composition of Todomatsu-Fir Trees

The results of the proximate chemical analysis of various parts in the two Todomatsu-firs are shown in Table 14. The Shiraoi fir being excellent in the growth is generally high in the solubility, especially in that with 1% NaOH solution, while its holocellulose and α-cellulose contents are lower than those of the Tomakomai fir with exception of the lower part wood. The nitrogen content is also high in the former.

5. Mineral Components in Tree Leaves

The leaves of *Picea jezoensis, Quercus mongolia* var. *grosseserrata, Tilia japonica, Kalopanax pictus* collected from the Tomakomai natural forests in autumn and *Abies sachalinensis* from the artificial forests were analyzed, as shown in Table 15 together with the analytical results of the leaves of *Sasa* and *Sasamorpha* species obtained in the undergrowths. Generally speaking, the leaves of the broad-leaved trees contain much nitrogen, while those of the coniferous trees and *Sasa* species are less. Meanwhile, the leaves of *Kalopanax pictus* have remarkably high ash content, in which silica is mostly occupied, as being similar to the *Sasa* species.

The leaves of the broad-leaved trees are on the whole rich in the nutrients essential for the tree growth. However, the content and the composition are different with individual species.

6. Buried Soils

It was indicated from the above facts the present soils of the Tomakomai district are immature soils due to the deposits only 240 to 300 years ago, and are infertile for the tree growth. Then, how had the land of this district been in the past? In order to investigate the properties of the past soils, two plots such as

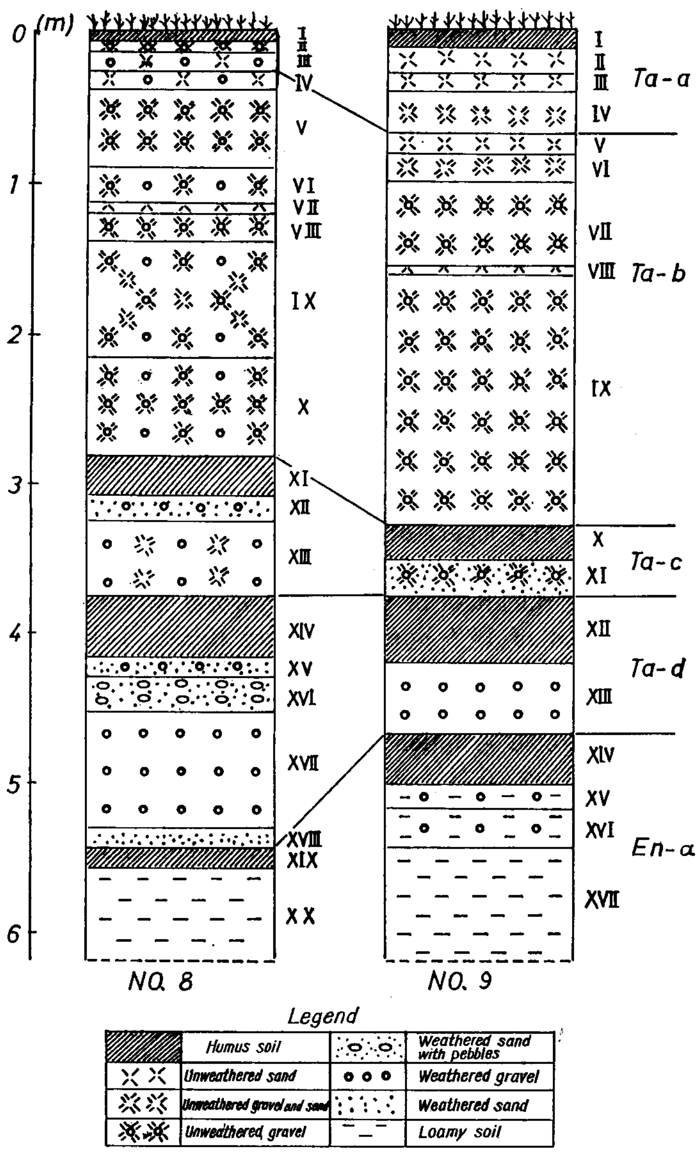

Fig. 4. Geological columnar sections of plot Nos. 8 and 9.

No. 8 and No. 9 were set up in surveying depth exceeding 5 m below ground. The properties of the soils under natural condition are shown in Tables 16 and 17. The columnar sections are also given in Fig. 4, contrasted with the designated symboles of the formations accumulated by the eruptions. Table 16 shows the buried soils observed at plot No. 8 were divided with naked eye into 20 layers, in which the layers from I to X seem to be composed of unweathered Ta-a and Ta-b formations having thicknesses of 28 cm and 248 cm, respectively. The XI to XIII layers with a 93 cm thickness seem to belong to Ta-c formation erupted in presumable age of 1,600 years B. P., though being different with the samples of carbon dating. The three layers are pedologically a little differentiated, i. e. the eleventh layer is a 25-cm thick A″ horizon colored black having been the topsoil at that time, the next is and B″ horizon of a thickness as thin as 15 cm, while the rest layer belongs to C″ horizon composed mostly of unweathered gravels, amounting to a 53-cm thickness. The next five layers differentiated to one A horizon and four B horizons are considered to be Ta-d formation brought about by the first eruption of Mt. Tarumae in the time of at least 3,000 to 5,000 years B. P. The layers have a thickness of 164 cm and the soils are fully developed to the mature called Ando soils, in which a 37-cm thick A‴ horizon, B_3''' and B_4''' horizons corresponding to XIV, XVII and XVIII layer, respectively, are rich in water. The 25-cm thick XVI layer containes unaccountably hard pebbles with a 5 to 6-cm diameter in a large quantity, which show the existence of a temporary stream at that time, as also reported in NAKAO's study.[9] The soils in XVII B_3''' layer colored orange were composed of fully weathered pumice gravels in an about 2-cm diameter, just like "Kanumatsuchi" produced in Tochigi Prefecture, and were easily powdered by crushing with fingers. The layers of XIX and XX appear to correspond to the parts of En-a formation accumulated by Mt. Eniwa's last eruption in the age of 9,000 years B. P. The thickness of this A⁗ horizon in brownish black color is relatively thin, while that of B⁗ horizon is very thick. Below the En-a formation, there would exist the En-b and En-c derived from the eruptions of the same mountain and they are followed by the formations of Spfl, Spfa-1 and Spfa-2 accumulated by the Shikotsu eruptions, as the base of this district.[2,12]

As shown in Table 17, the buried soils at plot No. 9 were divided into 17 layers in which the upper 9 layers of unweathered soils seem to correspond to Ta-a and Ta-b formations having thicknesses of 65 cm and 263 cm, respectively. The next layers of X and XI derived from Ta-c are 47 cm thick, differentiating into A and C horizons and lack in B horizon due to insufficient differentiation. The soils of the two XII and XIII layers from Ta-d formation with a 92 cm thickness are fully weathered and have low apparent specific gravities containing a bit of gravels as well as high moisture contents. But the soils of thirteenth layer remaining in the weathered gravels of an about 2-cm diameter in the field, were easily powdered on sieving after air-drying by crushing down with fingers. The soils of the next XIV to XVII layer seem to correspond to the parts of En-a formation, differentiated to a A horizon and three B horizons. Within the observation of these all layers, no pebbles were recognized, as seen in the XVI layer at plot No. 8.

Particle-size distribution of gravels in the soils at plot No. 9 were examined, as shown in Table 18. Generally the percentage of gravels exceeding 2 cm in diameter is low. The soils obtained from I to XI layer have a considerable amount of gravels, while those of the lower rest layers contain a little or no gravels.

Table 18. Particle-size distribution of gravels at plot No. 9 (%)

Layer	Thickness (cm)	Particle-size (mm)					
		>20	20–10	10–4	4–2	Total gravel	2>
I A	9	0	1	7	7	15	85
II C_1	16	0	1	9	14	24	76
III C_2	11	0	0	8	6	14	86
IV C_3	29	3	19	12	9	43	57
V C_1'	10	5	10	22	11	48	52
VI C_2'	19	7	18	6	0	31	69
VII C_3'	58	14	32	10	0	56	44
VIII C_4'	4	4	16	20	0	40	60
IX C_5'	172	2	22	37	2	63	37
X A''	21	0	0	9	7	16	84
XI C''	26	1	9	28	0	38	63
XII A'''	42	0	0	0	0	0	100
XIII B'''	50	0	0	3	4	7	93
XIV A''''	36	0	0	0	0	0	100
XV B_1''''	13	1	1	3	0	5	95
XVI B_2''''	28	1	1	1	0	3	97
XVII B_3''''	—	0	0	0	0	0	100

Physical and chemical properties of fine soils obtained from the buried soils at plots No. 8 and No. 9 are shown in Tables 19 and 20, respectively. In Table 19, the soils from the upper 10 layers are similar to the soils on the natural and man-made forests above-mentioned in the texture and the density as well as the chemical properties. However, the lower horizon soils show the properties of developed soils as well as typical volcanic ash soils such as low bulk density, high CEC, high absorption of P_2O_5 *etc.* except those of the thirteenth layer. Moreover, the soils contain relatively less clay and show loamy textures (SL, SCL or CL) and almost neutral in pH. The A''' horizon soils of XIV layer as considerably thick as 37 cm have the highest carbon content, from which it is inferable that there have been the long stable state around this district growing abundantly the plants.

In Table 20, the soils till VIII layer show the properties of immature soils similar to the soils described in the previous chapters. But the soils of the lower layers were weathered enough to show the characteristics of volcanic ash soils (black soils or Ando soils), having the properties identical with the buried soils at plot No. 8. The soils of XII A''' horizon derived from Ta-d with a 42-cm thickness

Table 19. Physical and chemical properties of buried fine soils at plot No. 8

Layer	Mechanical analysis (%)				Soil texture	Air-dried moisture (%)	Maximum water holding capacity (water ratio %)	Bulk density	Real specific gravity	pH		Exchange acidity
	Coarse sand	Fine sand	Silt	Clay						H_2O	N-KCl	
I A	60	17	9	14	S L	2.18	80.5	0.88	2.63	5.4	4.5	1.7
II C_1	76	14	6	4	S	1.00	29.1	1.44	2.91	5.7	4.7	1.4
III C_2	95	2	2	1	S	0.35	24.1	1.40	2.99	6.1	5.3	0.4
IV C_1'	89	4	2	5	S	1.16	33.6	1.35	2.86	6.0	5.0	0.5
V C_2'	97	1	1	1	S	0.18	22.1	1.36	2.94	6.2	5.8	0.3
VI C_3'	85	7	5	3	S	0.33	22.8	1.56	2.95	6.9	6.3	0.1
VII C_4'	87	5	5	3	S	0.25	20.6	1.54	2.97	6.9	6.7	0.2
VIII C_5'	86	6	4	4	S	0.17	21.1	1.53	2.87	6.9	6.4	0.2
IX C_6'	94	3	1	2	S	0.13	23.0	1.51	2.96	6.8	6.6	0.2
X C_7'	91	2	2	5	S	0.39	24.2	1.60	3.01	6.5	5.8	0.1
XI A''	67	7	6	20	S C L	6.50	98.8	0.77	2.42	5.7	4.8	0.5
XII B''	56	7	8	29	S C	4.00	59.2	1.02	2.67	5.9	5.2	0.2
XIII C''	95	2	1	2	S	0.80	26.5	1.38	2.85	6.2	5.8	0.1
XIV A'''	63	10	6	21	S C L	11.48	141.1	0.65	2.42	6.0	5.0	0.4
XV B_1'''	74	5	3	18	S C L	8.12	64.9	1.05	2.73	6.1	5.4	0.2
XVI B_2'''	82	3	2	13	S L	2.18	50.6	1.13	2.74	6.3	5.5	0.1
XVII B_3'''	71	10	5	14	S L	27.49	210.4	0.53	2.76	6.2	5.6	0.2
XVIII B_4'''	73	5	2	19	S C L	12.30	109.7	0.68	2.67	6.2	5.3	0.2
XIX A''''	37	12	26	25	C L	6.62	94.9	0.84	2.55	6.0	4.8	0.2
XX B''''	44	24	12	20	S C L	8.40	87.6	0.86	2.72	6.2	4.9	0.2

Loss on ignition (%)	C (%)	N (%)	C-N ratio	Total organic matter (%)	Isolated R_2O_3 (%)	CEC (me/100 g)	Exchangeable cations (me/100 g)				Degree of base saturation (%)	Absorption coefficient of P_2O_5 (mg/100 g)
							Ca	Mg	K	Na		
11.0	5.84	0.335	17	10.7	0	17.33	8.20	1.09	0.24	0.08	56	560
3.6	1.25	0.096	13	2.3	0.9	7.17	1.78	0.21	0.05	0.05	29	430
0.9	0.36	0.016	23	0.7	0.4	1.91	0.25	0.04	0.03	0.02	18	120
3.5	1.39	0.096	15	2.6	1.0	3.93	1.47	0.16	0.05	0.03	44	440
0.3	0.04	0.004	10	0.1	0.4	0.62	0.21	0.02	0.06	0.02	50	40
0.4	0.12	0.010	12	0.2	0.3	1.63	1.00	0.02	0.07	0.20	79	60
0.3	0.12	0.002	60	0.2	0.4	3.78	1.79	0.08	0.10	1.27	86	30
0.3	0.13	0.002	65	0.2	0.3	3.49	1.32	0.08	0.08	1.09	74	40
0.2	0.10	0.005	20	0.2	0.9	1.69	0.69	0.05	0.00	0.00	44	80
0.9	0.24	0.005	48	0.4	0.5	1.51	0.58	0.05	0.04	0.09	50	180
17.0	7.66	0.175	44	14.0	2.2	25.08	4.57	0.73	0.11	0.00	22	2,130
6.8	1.45	0.089	16	2.7	5.2	11.36	1.56	0.34	0.45	0.24	23	1,370
2.0	0.50	0.014	36	0.9	1.4	3.49	0.50	0.08	0.44	0.00	29	320
27.4	12.41	0.265	47	22.7	2.9	50.64	18.75	3.41	1.58	0.70	48	2,650
5.9	2.95	0.156	19	5.4	10.4	16.79	2.24	0.22	1.10	0.25	23	2,160
7.4	1.43	0.081	18	2.6	7.4	18.39	4.37	1.09	0.60	0.00	33	1,570
18.4	1.88	0.048	39	3.4	6.8	25.94	5.37	0.87	0.84	0.00	27	3,250
8.5	0.52	0.017	31	1.0	4.9	15.13	1.80	0.27	1.19	0.22	23	1,620
16.0	6.39	0.185	35	11.7	2.8	57.89	20.96	3.51	1.66	0.70	46	1,800
8.6	0.73	0.042	17	1.3	4.1	26.70	7.03	1.27	1.42	0.93	40	1,590

Table 20. Physical and chemical properties of buried soils at plot No. 9

Layer	Mechanical analysis (%)				Soil texture	Air-dried moisture (%)	Maximum water holding capacity (water ratio %)	Bulk density	Real specific gravity	pH		Exchange acidity
	Coarse sand	Fine sand	Silt	Clay						H_2O	N-KCl	
I A	64	16	8	12	S L	3.11	73.4	0.92	2.76	5.4	4.6	0.9
II C_1	90	5	2	3	S	0.54	24.2	1.41	2.98	5.8	4.9	0.3
III C_2	91	5	1	3	S	0.78	30.2	1.32	2.87	5.9	5.0	0.4
IV C_3	97	1	1	1	S	0.33	24.2	1.40	2.96	6.1	5.3	0.2
V C_1'	71	13	7	9	S L	0.60	20.4	1.63	2.74	5.9	5.2	0.1
VI C_2'	87	6	2	5	S	0.35	22.2	1.54	2.94	6.1	5.4	0.2
VII C_3'	97	1	1	1	S	0.25	20.4	1.56	3.04	6.2	5.5	0.2
VIII C_4'	83	9	5	3	S	0.50	20.7	1.52	2.89	6.2	5.4	0.2
IX C_5'	93	3	3	1	S	0.30	18.7	1.60	3.02	6.4	5.7	0.1
X A''	71	6	5	18	S C L	3.97	85.6	0.81	2.66	5.9	5.0	0.3
XI C''	86	4	2	8	L S	1.14	34.6	1.40	2.80	6.0	5.2	0.2
XII A'''	34	16	14	36	LiC	7.39	140.8	0.62	2.50	5.8	4.5	0.2
XIII B'''	69	8	9	14	S L	10.95	130.8	0.59	2.31	5.8	5.3	0.3
XIV A''''	59	9	11	21	S C L	7.26	104.3	0.73	2.45	6.1	5.1	0.2
XV B_1''''	47	24	18	11	S L	6.19	86.5	0.80	2.74	6.2	5.3	0.2
XVI B_2'''''	41	25	18	16	S C L	6.61	88.8	0.80	2.72	6.3	5.2	0.2
XVII B_3''''	29	25	28	18	C L	6.63	87.8	0.80	2.68	6.3	5.1	0.3

Loss on ignition (%)	C (%)	N (%)	C-N ratio	Total organic matter (%)	Isolated R_2O_3 (%)	CEC (me/100 g)	Exchangeable cations (me/100 g)				Degree of base saturation (%)	Absorption coefficient of P_2O_5 (mg/100 g)
							Ca	Mg	K	Na		
9.5	3.95	0.290	14	7.2	0	13.84	4.57	1.00	0.82	0.48	50	760
1.5	0.68	0.050	14	1.3	0.6	3.52	0.51	0.09	0.13	0.00	21	370
1.2	0.56	0.050	11	1.0	0.8	3.65	0.71	0.08	0.68	1.33	77	450
0.4	0.19	0.010	19	0.4	0.4	2.87	0.10	0.00	0.41	1.36	65	180
0.9	0.45	0.031	15	0.8	0.6	3.18	0.80	0.08	0.67	1.34	91	190
0.5	0.27	0.017	16	0.5	0.6	3.09	0.10	0.00	0.03	1.35	48	80
0.4	0.18	0.010	18	0.3	0.3	3.42	0.10	0.00	0.49	1.51	61	60
1.4	0.44	0.031	14	0.8	0.8	5.62	0.05	0.08	0.44	1.41	35	290
0.6	0.32	0.029	11	0.6	0.4	2.87	0.10	0.00	0.08	1.34	53	30
13.8	5.39	0.272	20	9.9	4.0	23.90	10.26	1.31	0.27	1.48	56	1,760
4.5	1.15	0.083	14	2.1	3.0	7.77	1.37	0.13	1.42	1.25	54	800
32.6	15.27	0.341	45	28.0	4.8	75.96	24.70	3.36	0.34	2.97	42	2,520
12.0	2.83	0.110	26	5.2	6.0	31.23	6.80	1.67	1.51	0.83	35	2,690
18.0	5.33	0.198	27	9.8	4.4	36.37	17.96	3.41	1.33	0.96	65	2,350
8.4	1.20	0.088	14	2.2	4.3	24.73	6.07	1.43	1.37	0.99	40	1,750
7.7	0.84	0.073	12	1.5	5.3	24.70	5.26	1.50	1.36	1.08	37	1,600
7.3	0.64	0.029	22	1.2	4.8	28.21	5.70	1.51	0.90	1.31	33	1,650

Table 21. Moisture contents at various pF values of buried fine soils at plot No. 8 (water ratio %)

Layer	pF							Available moisture (points)
	0	1.6	2.7	3.1	3.9	4.2	5.7	
I A	80.5	46.8	34.2	28.8	18.2	14.6	2.2	32.2
II C_1	29.1	12.4	7.5	6.2	3.7	2.7	1.0	9.7
III C_2	24.1	5.5	4.2	3.6	2.4	2.0	0.4	3.5
IV C_1'	33.6	12.2	8.3	6.8	3.9	2.6	1.2	9.6
V C_2'	22.1	4.4	3.2	2.9	1.8	1.4	0.2	3.0
VI C_3'	22.8	5.4	4.6	3.3	1.9	1.5	0.3	3.9
XVII C_4'	20.6	5.9	4.4	3.1	1.4	0.8	0.3	5.1
VIII C_5'	21.1	6.0	4.2	3.0	1.8	1.2	0.2	4.8
IX C_6'	23.0	5.2	4.1	1.8	1.1	0.6	0.1	4.6
X C_7'	24.2	5.8	3.4	2.7	1.3	0.9	0.4	4.9
XI A''	98.8	53.3	36.8	31.7	20.8	18.8	7.0	34.5
XII B''	59.2	29.5	21.2	18.1	12.5	10.0	4.2	19.5
XIII C''	26.5	8.3	5.5	4.4	2.1	1.3	0.8	7.0
XIV A'''	141.1	90.2	67.8	59.6	43.1	36.6	13.0	53.6
XV B_1'''	64.9	34.0	24.4	20.5	14.0	13.2	8.8	20.8
VI B_2'''	50.6	17.4	8.4	5.9	3.7	3.1	2.2	14.3
XVII B_3'''	210.4	137.9	98.3	84.2	61.3	57.9	37.9	80.0
XVIII B_4'''	109.7	71.4	51.3	45.0	38.0	35.8	14.0	35.6
XIX A''''	94.9	63.4	46.2	39.6	27.3	24.9	7.1	38.5
XX B''''	87.6	66.5	47.6	41.2	25.8	21.2	9.2	45.3

Table 22. Moisture contents at various pF values of buried fine soils at plot No. 9 (water ratio %)

Layer	pF							Available moisture (points)
	0	1.6	2.7	3.1	3.9	4.2	5.7	
I A	73.4	35.5	21.8	17.4	11.6	9.6	3.2	25.9
II C_1	24.2	6.3	4.8	4.1	2.5	2.2	0.5	4.1
III C_2	30.2	11.2	7.7	6.4	3.9	2.8	0.8	8.4
IV C_3	24.2	5.8	4.2	3.5	2.2	1.6	0.3	4.2
V C_1'	20.4	11.1	6.3	4.3	2.5	2.0	0.6	9.1
VI C_2'	22.2	7.2	4.3	3.4	1.7	1.2	0.4	6.0
VII C_3'	20.4	3.5	2.7	2.1	1.4	1.1	0.3	2.4
VIII C_4'	20.7	7.1	5.9	4.9	2.9	2.2	0.5	5.9
IX C_5'	18.7	5.1	2.7	2.0	1.1	0.8	0.3	4.3
X A''	85.6	54.4	38.1	32.4	20.9	18.6	4.1	35.8
XI C''	34.6	16.2	10.9	8.6	4.9	3.5	1.2	12.7
XII A'''	140.8	108.2	75.5	62.8	39.5	33.1	8.0	75.1
XIII B'''	130.8	96.1	69.6	59.1	38.3	33.0	12.3	63.1
XIV A''''	104.3	84.0	59.1	49.9	32.6	27.8	7.8	56.2
XV B_1''''	86.5	60.8	43.2	36.4	23.5	21.2	6.6	39.6
XVI B_2''''	88.8	73.8	51.6	43.5	26.7	23.3	7.1	50.5
XVII B_3''''	87.8	69.8	44.5	38.1	25.0	20.8	7.1	49.0

contain carbon as high as some 15 percent, while the soils of XIV A'''' horizon of brownish black derived from En-a have a carbon content of about 5 percent. Compared with plot No. 8 of the flat land, the soils obtained from No. 9 on the terrace facing to the coast, show a little high exchangeable sodium.

The moisture contents at various pF values of plot No. 8 and No. 9 are shown in Tables 21 and 22, respectively. The more weathered the soils are, the higher the water retention is. In the weathered soils the available water is richly contained, especially in the soils of the A horizons and the layers derived from Ta-d and En-a formations.

Mineral composition of the soils from plot No. 8 and No. 9 are given in Tables 23 and 24, respectively. Taking a general observation of these data, the content of silica is the highest but does not exceed 60 percent, while the humeous soils corresponding to A horizon have less than 50 percent of silica. Though alumina content varies with the layers, it increases gradually toward the lower layers, accompanied with a decrease of the content of ferric oxide, seemingly compensational each other. Silica to alumina ratio is considered to be high in unweathered soils of the upper layers and low in the developed mature soils of the lower layers. It may be attributed to the production of clay minerals. The content of calcium and magnesium oxides is high in the upper soils but low in the lower ones. As A horizons containing much humus materials are unexpectedly low in these components including potassium oxide, the phenomena of leaching or eluvial action may happen. The content of sodium oxide, however, is high probably owing to the precipitation involving sodium chloride in sea water, while phosporic acid less leachable is a little high in A horizons combined with active alumina, being characteric of weathered volcanic ash soils.

Finally, the buried soils would be sammarized up, discussing the soil genesis from these results: The land of Tomakomai district was completed by the partially tuffaceous accumulations ejected by Shikotsu eruptions in the age of 32,000 years B. P. The formations of En-c, -b and -a are ridden on them, inserting Atsubetsu gritty formation. The lowest formation observed at plot No. 8 and No. 9 corresponds to En-a accumulated by Mt. Eniwa's eruption in the age of presumable about 9,000 years B. P., though being differently reported by various carbon dating. Thereafter, Mt. Tarumae begins to be active as the eruption for Ta-d formation amounting to 90 to 150-cm thickness in the age of about 5,200 years B. P. The period making superficial lands of En-a is calculated to be as long as 3,800 years. But A'''' horizon of the plots is brownish black in color and is relatively low in carbon content by 5 to 6 percent, therefore it is considered the vegetation growths were not so prosperious on the land at that time. According to pollen analysis of the layer,[7,8] pollens and spores are also scarcely recognized, which may be of course, decomposed by a huge amount of heated ejecta over 200°C forming Ta-d. though the membraneous sporopollenin is said to be resistant to chemicals and heat. These deposits are fully developed to mature soils differentiating B horizons. If the time of Ta-c eruption is about 1,600 years B. P., the period of superficial

Table 23. Mineral components of buried fine soils at plot No. 8

Layer	Thickness (cm)	Apparent specific gravity		N (%)	Residue on ignition (%)	Components as oxides (%)									Silica-alumina ratio
		Fresh soil	Oven-dried soil			SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	K_2O	Na_2O	P_2O_5	Total	
I A	6.5	0.89	0.59	0.335	89.0	54.3	12.1	7.9	2.2	2.9	0.4	1.1	0.17	81.07	7.1
II C_1	8	1.09	0.80	0.096	96.4	58.4	9.0	11.7	4.6	7.1	0.2	1.3	0.06	92.36	10.8
III C_2	13	1.19	0.99	0.016	99.1	58.4	11.5	10.2	3.8	6.9	0.3	1.6	0.07	92.77	8.8
IV C_1'	8	1.22	0.95	0.096	96.5	57.2	11.3	9.3	5.0	7.7	0.3	1.2	0.09	92.09	8.6
V C_2'	50	1.09	0.93	0.004	99.7	57.6	12.4	14.4	4.3	6.9	0.4	1.5	0.08	97.58	8.0
VI C_3'	25	0.92	0.67	0.010	99.6	58.9	13.4	9.8	3.9	7.0	0.6	1.5	0.11	95.21	7.5
VII C_4'	5	1.17	0.98	0.002	99.7	59.6	11.8	11.0	4.3	7.7	0.1	1.2	0.09	95.79	8.3
VIII C_5'	20	0.98	0.77	0.002	99.7	58.6	10.5	13.7	5.1	7.4	0.3	1.4	0.08	97.08	9.7
IX C_6'	75	1.01	0.78	0.005	99.8	58.3	9.9	13.2	5.5	7.4	0.2	1.3	0.07	95.87	9.7
X C_7'	65	0.78	0.52	0.005	99.1	59.2	13.3	9.4	2.7	8.5	0.6	1.6	0.04	95.24	7.5
XI A''	25	1.25	0.58	0.175	83.0	49.1	13.9	8.1	2.6	4.3	0.3	1.2	0.15	79.65	5.8
XII B''	15	1.23	0.87	0.089	93.2	58.5	14.1	9.8	3.0	4.3	0.5	1.3	0.10	91.60	6.9
XIII C''	53	1.08	0.83	0.014	98.0	55.6	14.5	11.1	5.0	8.9	0.2	1.2	0.07	96.57	6.6
XIV A'''	37	0.98	0.41	0.265	72.6	43.9	12.6	8.5	1.8	2.3	0.3	0.8	0.26	70.46	6.1
XV B_1'''	11	1.16	0.85	0.156	94.1	49.3	18.2	9.3	3.7	4.2	0.2	1.2	0.10	86.20	4.6
XVI B_2'''	25	1.25	0.98	0.081	92.6	50.0	17.5	10.5	5.0	5.8	0.2	1.2	0.04	90.24	4.9
XVII B_3'''	79	0.81	0.27	0.048	81.6	46.6	18.2	10.4	1.8	3.1	0.1	0.7	0.15	81.05	4.1
XVIII B_4'''	12	0.85	0.45	0.017	91.5	55.7	19.5	7.8	2.7	2.4	1.1	1.5	0.07	90.77	4.7
XIX A''''	13	1.33	0.66	0.185	84.0	53.3	14.5	5.8	1.1	2.7	0.3	1.0	0.16	78.86	6.3
XX B''''	—	1.20	0.78	0.042	91.4	57.3	16.9	6.3	2.0	1.7	1.0	1.0	0.12	86.32	5.6

Table 24. Mineral components of buried fine soils at plot No. 9

Layer	Thickness (cm)	Apparent specific gravity		N (%)	Residue on ignition (%)	Components as oxides (%)									Silica-alumina ratio
		Fresh soil	Oven-dried soil			SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	K_2O	Na_2O	P_2O_5	Total	
I A	9	1.08	0.77	0.290	90.5	52.8	11.8	11.4	2.7	3.0	0.4	1.3	0.15	83.55	7.3
II C_1	16	1.24	1.04	0.050	98.5	58.3	13.9	10.1	4.1	6.8	0.3	1.3	0.10	94.90	6.9
III C_2	11	1.29	1.11	0.050	98.8	57.6	13.1	8.4	4.4	7.4	0.3	1.2	0.07	92.47	7.4
IV C_3	29	1.23	1.08	0.010	99.6	57.8	12.0	11.4	5.0	6.8	0.4	1.4	0.06	94.86	8.0
V C_1'	10	1.34	1.12	0.031	99.1	58.7	15.2	8.2	3.6	8.3	0.4	1.1	0.09	95.59	6.5
VI C_2'	19	1.21	0.99	0.017	99.5	58.1	16.7	9.3	3.8	8.4	0.4	1.4	0.05	98.15	6.0
VII C_3'	58	1.05	0.79	0.010	99.6	58.3	9.9	13.8	5.5	7.8	0.2	1.1	0.09	96.69	9.7
VIII C_4'	4	1.16	0.96	0.031	98.6	58.1	13.0	10.7	4.6	7.5	0.4	1.3	0.07	95.67	7.4
IX C_5'	172	0.86	0.61	0.029	99.4	59.1	9.1	14.4	5.5	7.4	0.1	0.9	0.06	96.56	10.9
X A''	21	1.24	0.76	0.272	86.2	51.8	11.6	11.0	2.6	4.2	0.4	1.1	0.13	82.83	7.8
XI C''	26	1.10	0.87	0.083	95.5	55.2	13.0	13.2	4.7	5.7	0.2	1.0	0.08	93.08	7.1
XII A'''	42	1.02	0.46	0.341	67.4	41.5	11.2	5.6	1.5	1.8	0.6	0.9	0.25	63.35	6.3
XIII B'''	50	0.96	0.43	0.110	88.0	51.1	18.0	8.7	2.2	3.4	0.3	1.0	0.09	84.79	4.7
XIV A''''	36	1.17	0.54	0.198	82.0	49.7	15.4	7.8	2.2	2.1	0.7	1.1	0.16	79.16	5.5
XV B_1''''	13	1.27	0.71	0.088	91.6	54.9	16.7	7.7	2.4	2.5	0.8	1.0	0.06	86.06	5.7
XVI B_2''''	28	1.02	0.61	0.073	92.3	57.2	18.0	6.8	1.9	2.3	0.9	1.2	0.06	88.36	5.3
XVII B_3''''	—	1.24	0.68	0.029	92.7	59.0	19.4	6.0	1.3	0.9	1.0	1.4	0.08	89.08	5.2

land of Ta-d continues for 2,850 years the second longest in this district. The soils of A‴ horizon with thicknesses of 37 to 42 cm contain cabon as high as 12 to 15 percent, showing the feature of typical black soils. The results of the pollen analysis[7,8] show the district was a grassland growing mainly *Gramineae* at that time, though the numbers observed are relatively a few. Meanwhile, the age of Ta-c continues for 1,300 years, until Ta-b was formed by the eruption in 1667 A. D. The period of the 1,300 years seems to be necessary at least for the process of the soil differentiation forming B horizon; one possesses B″ horizon and the other does not, while A″ horizon at the two plots 21 to 25-cm of thickness, the soils of which contain a considerable smount of humus including the pollens of *Quercus, Ulmus, Alnus, Picea* and *Gramineae etc.* and the spores of *Polypodiaceae, Osmunda etc.* as the undergrowths.[7,8] These distributions show that the circumstance of the Ta-c age in this district is very similar to the present days. The period when Ta-b formation was the top is only 72 years due to the deposits of Ta-a in 1739 A. D. Moreover, as shown in Fig. 5, tremendous ejecta of the Ta-b are observed in a wide area and much thickness. This fact is considered that the land had been arid for several decades without natural vegetations and that A′ horizon, therefore, did not formed. On the contrary, the present superficial

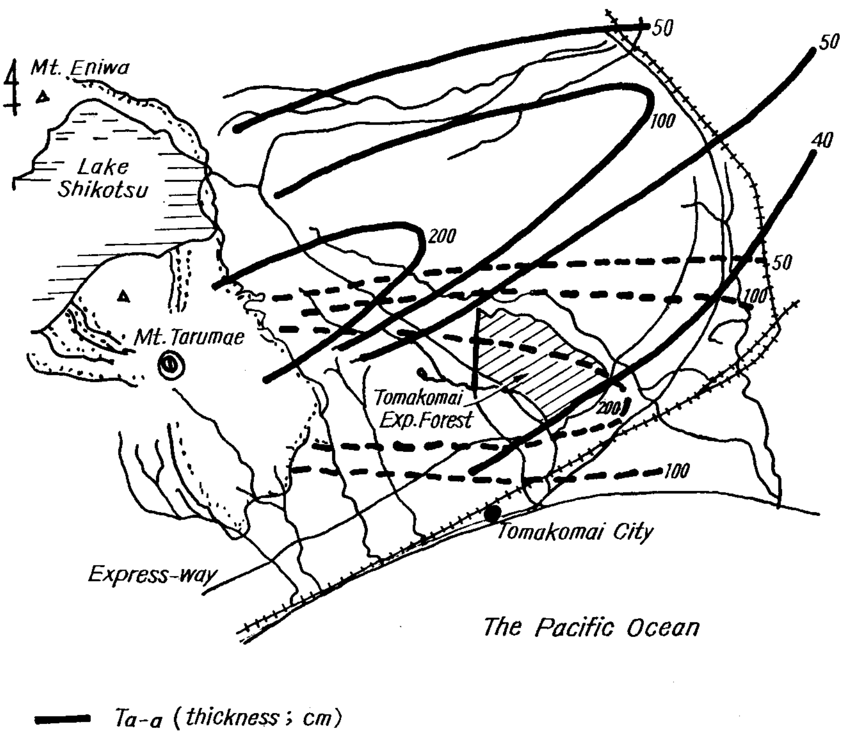

Fig. 5. Thickness and direction of Ta-a and Ta-b formations.

land from Ta-a formation is maintaining for 240 years, forming immature soils differentiated to a brownish black A horizon with a thickness of 10 cm on the C horizons.

Although the rate of soil development varies with time, together with the actions of climate, vegetations and organisms, as well as topography and parent materials, the material consisting of volcanic ashes may be easily transformed into an immature soil or young soil (Entisols) with the differentiation of A and C horizons in a relatively short period of time such as 200 years, if the conditions are favorable. The mature stage (Mollisols) in which the highest land productivity is found, may be, however, attained with the differentiation of B horizon by the elapse of at least more than 1,300 years in this district.

Conclusions

The superificial soils covering the whole area of Tomakomai district consist of immature soils derived from Ta-a and Ta-b ejected by Mt. Tarumae's eruptions in 1739 and 1667 A. D., respectively. The results of the soil investigation of the natural forests and Todomatsu-fir plantation stands show that the soils are mainly composed of gravels and sands and lack in the nutrients and water holding capacity except IA layer. Accordingly, the tree growths are generally low, together with the worse climatic condition. But the stand density is relatively high and the growth in juvenile trees is energetic by an uptake of the nutrients contained in A_0 and IA layer.

Meanwhile, the results investigated on the buried soils reveal that the soils of the lower layers derived from Ta-d and En-a formation by the eruptions in the ages of 5,200 and 9,000 years B. P., respectively are fully differetiated to form B horizons, and developed to the mature soils having the properties of typical volcanic ash soils (black soils). On the contrary, the buried soils derived from Ta-c by the eruption in the age of 1,600 years B. P. seem to have maintained the surface land for about 1,300 years and are barely differentiated to B horizon. From these facts the period of at least more than 1,300 years may be necessary for the volcanic deposits to attain the mature soils giving the highest productivity in this district.

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摘　　要

苫小牧地方は，北海道中央南部石狩勇払低地帯と，樽前山および支笏湖を擁した台地からなり，北海道大学苫小牧地方演習林は，その丘陵の南部に位置している。1904年創設以来，札幌に近いこともあって，育林学をはじめとする多くの研究や，学生実習に広く利用されてきた。しかし，この地域の立地条件から，人工林の育成はかなり困難であると思われる。本研究では，この理由を土壌の面から追究した。まず，苫小牧地方演習林の天然林とトドマツ造林地の土壌および埋没土について，その原土の調査，細土の理化学的性状を分析した。さらにこの付近で最も生育が良好といわれる白老営林署管内のトドマツ造林地の土壌を対照として調査し，あわせて40年をこえるトドマツ造林木を両調査地より伐採して樹幹解析した。また，この代表木を各部位に分けて化学分析するとともに，苫小牧地方演習林に生育している主要な樹木の葉とササの葉の無機分析を行った。

埋没土については，これまで火山灰年代学的にかなり詳しく調べられているが，本研究では，これを土壌学的に追究することにより，それぞれの年代で土壌はどのような状態であったか，また現在表層を形成している未熟土は，どの位の期間を経過することによって，生産力の高い完熟土になるかを推測することができた。

これらの調査・分析の結果は次のとおりである。

1) 苫小牧地域を被っている表層の土壌は，1667年と1739年の樽前山の噴火により堆積された未熟土からなっている。

2) この地域は，森林植物帯上汎針広混交林帯の南部に属するため，主としてミズナラ，カツラ，ハリギリ，サワシバ，タモ類，シナノキ，アサダ，ハルニレ，カンバ類，キハダ等の広葉樹の他，針葉樹としてエゾマツとトドマツが見られる。一方，林床植生は，多種類の低木をはじめ，オシダや，タツノヒゲ，スズタケを含む種々のイネ科等からなっている。(Table 2)

3) 天然林の樹種は豊富で，その密度は高いが，生長は劣り，施業を実行していない同演習林の保存林では，その立木蓄積は104 m^3/haであった。(Table 2)

4) 樹木の細根が見られる深さまで掘った試孔の範囲内で，土壌は肉眼観察の結果，プロ

ットにより4または5層に分かれる。6から16 cmの厚さをもつIA層の他は，総て礫および砂からなる未風化母材のC層である。しかし，III層ないしIV層の土壌はやや黒みがかった層でTa-bの表土だった層と考えられる。けれども，その期間はわずか70年と短かかったため，A層までには発達せずC層の様相を呈していた。(Table 3)

5) 天然林の細土は，IA層を除き，ほとんど砂土からなり，風乾水分，最大容水量は低い。また化学的には，pHは中性に近く，炭素・窒素含有量，陽イオン交換容量，リン酸吸収係数も低かった。しかし，A_0層およびIA層は水分保持力や栄養分に富み，恐らく樹木は，ここに細根をのばして生育しているものと推察される。(Table 4–6)

6) トドマツ造林地を白老管内のそれと比較すると，ほぼ同じ林齢(樹齢42年と44年)と同様な立木本数で著しい生長の差が見られる。苫小牧地方演習林の平均木は，高さ10.5 m，胸高直径14.4 cmであるのに対し，白老産の平均木は，17.9 m，21.3 cmであった。したがって，蓄積も前者の116 m^3/haに対し，後者は394 m^3/haにも達していた。(Table 7)

7) この生長力の差は主として土壌の性質に起因していることが，土壌分析の結果から推測された。苫小牧の未熟土壌に対し，白老営林署管内のトドマツ造林地の土壌は，Us-c(有珠山噴出物)と思われる火山灰土壌からなる沖積土であるが，ぼう軟で土性はローム質であり，水分保持力が高く，化学的にも極めて良好である。しかし，土壌三相をみると，白老の土壌は固相の占める割合が小さく，それにともなって孔隙量が極めて大である。(Table 8–10)。

8) 苫小牧と白老産トドマツ上層木の代表的なものを樹幹析解した結果は，樹齢10年頃まではむしろ前者の生長が大であるが，その後は著しく低下し，40年を経た樹木で，大きな相違がでている。(Table 12, 13, Fig. 2, 3)

9) これらのトドマツを，いろいろな部位に分けて，化学分析をしたところ，白老産のトドマツは，下部を除いて，一般に抽出物の量が多く，また窒素分に富んでいる。(Table 14)

10) 樹葉の無機分析の結果は，樹種によってその量，成分が異なるが，広葉樹の灰分は針葉樹に較べて高い。しかし，一緒に分析したササ類の葉では，灰分は著しく高く，とくにミヤコザサでは，17%近くにも達している。また広葉樹は，無機栄養物である窒素・カリ・リン酸および石灰の含有率が高い。一方，珪酸は，エゾマツ，ミズナラの樹葉では比較的高いが，ササの場合は灰分の70～80%を珪酸が占めていた。(Table 15)

11) 深さ5 mにわたる埋没土壌(Plot No. 8 と No. 9)を分析した結果，Ta-aおよびTa-bの未熟土の厚さはあわせて275ないし328 cmであり，その直下にTa-cが埋没している。厚さ47ないし93 cmのTa-c層は，1,600年前頃の樽前山の噴火で堆積したものと思われる。(Table 16, 17, Fig. 4)

12) Ta-cが表層であった期間は，およそ1,300年と推定され，Plot No. 8ではA, B, C層に分化し，No. 9ではB層の生成は見られない。Ta-cのA層に相当するA″の層厚は25ないし21 cmで，6～7%の炭素を含み，土壌学的に良好である。一方，No. 8にのみ見られたB″

層はわずか 15 cm の厚さではあるが，砂質埴土 (SC) の土性となり，よく風化している。また両 Plot に現れている C″ 層はまったく未風化であった。(Table 18, 19)

13) Ta-c の下には，およそ 5,200 年前と推定される樽前山の噴火で堆積した Ta-d と，およそ 9,000 年前の恵庭岳の噴火で生成したと考えられている En-a 層があり，この両層とも十分に風化し，典型的な火山灰土壌あるいは黒色土壌の性質を示している。(Table 18, 19)

14) 一方，花粉分析の結果を参考にすると，Ta-c の A″ 層では，現在と同じ樹種および林床植生の花粉，胞子が観察されることから，現在とよく似た気象環境がうかがわれ，さらに Ta-d の時代では，海岸に近いところはイネ科の草原であったものと推測される。

15) これらの事実からは，この地域で火山堆積物が A, C 層に分化したいわゆる未熟土になるには 200 年内外を要する一方，現在苫小牧地域の表層を占めている未熟土が生産性の高い完熟土まで発達するには，今後 1,000 年以上 (降灰後 1,300 年以上) の年月が必要ということになる。したがって苫小牧地域の林業は，この現土壌を考慮した施業を実施し，多面的な価値のある森林を造成していくことが望まれる。